INTRODUCTION

1.1 INDIAN AGRICULTURE-AN OVERVIEW

Agriculture continued to be the backbone of the Indian economy. Indian agriculture has undergone tremendous metamorphosis especially during the post independence days, raising food grains production from 50.8 million tonnes in 1950-51 to 244.78 million tonnes (2010-11; comprising of 121.14 million tonnes during Kharif season and 123.64 million tonnes during the Rabi season), and is now estimated to be over 252.56 million tonnes in 2011-2012. (Source: Economic Survey, 2010-2011; Ministry of Agriculture, Govt. of India 2012). In the process, the country has progressed from a situation of food shortages and imports to one of surpluses and exports. While retrospecting this spectacular achievement, significant contribution of agricultural technologies, hard work of the farmers and enabling policy support from the Governments are found to be the prime mover in enhancing productivity.

It is mentionable that agriculture constitutes the lifeline of villages where more than 70% of Indian population lives. Increasing agricultural production for achieving food security for all has been the central focus of India's agricultural development strategy since independence. India's population is estimated to touch 1.4 billion by 2020 requiring more than 280 million tonnes of food grains and thus agricultural sector must grow by 4 per cent each year to support this huge number (ICRISAT Global Summit 2011). Food security will always remain a very sensitive issue in India, as the country has the largest concentration of poor and malnourished people in the world. (As 40% of worlds hungry people live in India and China alone. FAO STAT, 2012).

The government of India has taken several initiatives to motivate farmers to grow more pulses and to increase pulse production in the country. Increase in Minimum Support Price of pulses (to more than 30%) along with enhanced budgetary allocation had also led to increase in the area coverage under pulses from 22.76 million hectares in 2004-05 to 25.43 million hectares in 2011-12. The productivity of pulses has significantly increased from 577 kg per hectare in 2004-05 to 679 kg per hectare in 2011-12. (Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation 2012).

Pulses production strategies, along with a mix of policy and programmatic support have contributed significantly to the path breaking achievement of 18.24 million tonnes in 2010-11. Production of pulses however marginally lowered at 17.28

million tonnes during 2011-12. Various programmes by Govt. of India had been sharply focused for better monitoring and assured delivery of planned inputs and services to the farmers. The most notable of such programmes include; introduction of special initiative of Accelerated Pulses Production Programme under National Food Security Mission (2010), the e-pest surveillance programme of National Centre for Integrated Pest Management (NCIPM), as well as initiation of Integrated Development of Sixty Thousand Pulse Villages Scheme (2010-11)

A major increase in the productivity of pulses has been noticed in the states of Maharashtra and Uttar Pradesh during 2010-11. The increase in total production of pulses has been on account of improvement in production levels of Tur, Urad and Moong. The average annual growth rate of area, production and yield of pulses increased significantly during 2000-01 to 2010-11 in these states.

The all-time high pulse production of 18.24 million tonnes from 26.40 million ha for 2010-11, was achieved partly due to better access to quality seed of improved variety by farmers and partly due to increase in area. ICAR has made sincere efforts in enhancing breeder seed production of major pulse crops. Apart from the availability of quality seeds of high yielding varieties, strong technology back up from Indian Institute of Pulses Research (IIPR), Kanpur and its wide network of All India Coordinated Research Projects (AICRP) across the country, increase in minimum support prices and effective government programmes has helped in increasing pulses production. Varietal development in pulses is focused upon utilization of diverse sources in the hybridization programme to accumulate desirable alleles for agronomic traits and resistance to diseases and pests. (Source: Department of Agriculture and Cooperation Govt. of India, 2012)

The Indian seed programme largely adheres to a limited generation system for seed multiplication in a phased manner. The system recognizes three generations, namely breeder, foundation and certified seeds and provides adequate safeguards for quality assurance in the seed multiplication chain. The seed replacement rate has been improving, but much more can be done in this regard to give a boost to productivity through seed improvement.

1.2 ORIGIN AND BOTANICAL CLASSIFICATION OF PEA

The pea (*Pisum Sativum* L., 2n =2x= 14) sometimes called the English green or Common Pea was one of the earliest cultivated food crops, with its cultivation spreading though Europe, India and China by 2000 B.C. (Zohary et.al.,2000). Neither the wild progenitor nor the early history of pea is well known. Prior to cultivation, pea together with vetches, vetchlings and chickpeas was part of the everyday diet of hunter-gatherers at the end of the last Ice Age in the Middle East and Europe. Pea probably originated in southwestern Asia, possibly northwestern India, Pakistan or adjacent areas of former USSR and Afghanistan and thereafter spread to the temperate zones of Europe (Kay, 1979; Makasheva, 1983). Based on genetic diversity, four centers of origins, namely, Central Asia, the Near East, Abyssinia and the Mediterranean have been recognized (Gritton, 1980). Non-pigmented peas to be used as a vegetable were grown in United Kingdom in the middle Ages (Davies et al., 1985). Peas were introduced into United States soon after the colonists first settled in this country and after then a winter type pea was introduced from Austria in 1922. Pea was taken to China in the first century (Makasheva, 1983). Peas were reported to be originally cultivated as a winter annual crop in the Mediterranean region (Smart, 1990). Remains of pea occur at high frequencies in sites dating from the 10th and 9th millennia BC suggesting that domestication of grain legumes could even predate that of cereals. (Zohary et al., 2000). The modern-day garden pea is thought to have originated from the field pea that was native to central Asia and Europe and has been consumed by man for thousands and thousands of years.

Pea (*Pisum sativum* L.) belongs to genus Pisum, tribe Fabeae, family Fabaceae (till recently the Leguminosae), and subfamily Papilionaceae. According to modern nomenclature, *Pisum sativum* is used for all edible forms of peas. The “garden pea” and “field pea” are treated as subspecies within *Pisum sativum*. Garden peas are recognized as cultivars of *Pisum sativum* subspecies *hortense* and varieties of field peas as *pisum sativum* subspecies *arvense*. The word “Pea” have been derived from the Anglo-Saxon derivative “Pise” (name for the vegetable-plant and edible seed), apparently acquired from the Latin *pisum.* Later the word “Pise” mutated to the more familiar “Pease”. But the word was often mistaken by the ignorant for the plural of an imagined (but nonexistent) singular “pea”; over the centuries, that false singular form, from constant repetition, became the real form.

1.3 FLORAL BIOLOGY AND MODE OF REPRODUCTION

Pea (*Pisum sativum* L.) is a self pollinated annual herb, bushy or climbing, glabrous, usually glaucous; stems weak, round, and slender, 30-150 cm long; leaves alternate, pinnate with 1-3 pairs of leaflets and a terminal branched tendril leaflets ovate or elliptic, 1.5-6 cm long (Duke, 1981). The leaf type could be conventional, semi-leafless and leafless (Davies et al., 1985). The node at which the first flower emerges is characteristic of a given variety. Flowers borne on the same peduncle produce pods that mature at different times. Seeds are globose or angled, smooth or wrinkled, exalbuminous, whitish, gray, green, or brownish in color.

Pea is highly self pollinated due to cleistogamous flower structure and less than one percent out crossing usually takes place in it. The time of anthesis is usually after 4 PM in the evening.

1.4 IMPORTANCE AND UTILIZATION

The dried peas contain 27.8 percent protein as compared to wheat which contains only 9.4 per cent. Peas are an excellent human food, either eaten as a vegetable or used in preparation of soup. The peas add color and flavor to a great variety of dishes such as pizza toppings, omelettes, kedgree, soups, salads and curries etc.

The peas are full of nutrition because its grain is rich in protein (27.8%), complex carbohydrates (42.65%), vitamins, minerals, dietary fibers and antioxidant compounds (Urbano et al., 2003). In modern times peas are usually boiled or steamed which breaks down the cell walls and makes the taste sweeter and the nutrients more bioavailable.

In India, fresh peas are used in various dishes such as “Aaloo matar” (curried potatoes with peas) or “Matar paneer” (paneer cheese with peas), though they can be substituted with frozen peas as well. Peas are also eaten raw, as they are sweet when fresh. Split peas are also used to make dhal, particularly in northern India. In Japan, China, Taiwan and some Southeast Asian countries, including Thailand and Malaysia, peas are roasted and salted, and eaten as snacks.

1.5 MEDICINAL USES OF PEA

Among the food legumes, pea seeds can be used in the synthesis of bioplastics which are made from pea starch. Peas may help prevent certain types of cancers such as prostate cancer and are good for heart. Pea seed peptide fractions have less ability to scavenge free radicals than glutathione, but greater ability to chelate metals and inhibit linoleic acid oxidation (Pownall et al., 2010). However some people are allergic to peas. In Spain, pea flour is considered resolvent and is applied as a cataplasm. It has been reported that the seeds contain trypsin and chymotrypsin,which can be used as contraceptive, fungistatic and spermicide (Duke,1981).

1.6 CHEMISTRY OF PEA

Peas are good source of Vitamin A, Vitamin C, folate, thiamine (Vitamin B_1) iron and phosphorus. They are rich in protein, carbohydrate and fiber and low in fat (Bastian Elli, D, 1998). The largest chemical component in peas as in other legumes is carbohydrate (CHO) which constitute about 42.65% of seed weight, while amylose is about 34% of seed weight. (Bressani and Elias, 1988). However according to Hulse, (1994) the dried peas contain: 10.9% water, 22.9% protein, 1.4% fat, 60.7% carbohydrate, 1.4% crude fiber, and 2.7% ash.

1.7 AREA AND PRODUCTION

According to FAO statistics, global pulse production in 2010-11 (the latest year for which global data are available) was 67.71 million tonnes, which included 10.2 million tonnes of dry peas (mattar), 10.9 million tonnes of chickpeas, 4.6 million tonnes of lentils (masur), 23.2 million tonnes of dry beans, 5.5 million tonnes of cowpeas, 3.7 million tonnes of pigeon peas (tur), 4.3 million tonnes of broad beans and 4.4 million tonnes of other pulses (FAOSTAT, 2012).

Peas ranks 4th in the world on a production basis (441.53 thousand tons) among grain legumes after soybean, groundnut and French beans and is grown on an area of 528.71 thousand hectares in the world (FAO, 2012). In India the total area under pea production in 1999-2000 was 270 thousand hectares with a total production of 2071 thousand tonnes. The area under cultivation increased to 300 thousand hectares in 2001-2002. The area under pea cultivation and total production increased at a good rate from 2006-2007 up to 2010-2011. It includes total production of 2402, 2491,2916,3029,3199 thousand tonnes from an area of 297,313,348,365 and 397 during 2006-07, 2007-08, 2008-09, 2009-10 and 2010-11 respectively. In spite of the bumper production during last few years, India imported 1656 and 1505 thousand metric tonnes of dry peas during 2009-10 and 2010-11 respectively from the countries like Canada, USA, Australia, Russia and Ukraine to meet the domestic demand. (Source: Directorate of Economics & Statistics; Department of Agriculture & Cooperation, Govt. of India, 2012).

1.8 GENETIC RESOURCES AND GENETIC DIVERSITY

Crop improvement depends on the germplasm diversity existing in the crop of interest. Pea and other cool season food legume crops are produced under the vagaries of stresses, both biotic and abiotic. Evaluation of the germplasm for these stress conditions is critical to sustained pea production. Also incorporation of new traits into existing cultivars has been reported (Summerfield and Roberts, 1985; Muehlbauer, 1991). Incorporation of traits available in germplasm collections into adapted backgrounds has been proposed and appropriate breeding methods have been suggested (Muehlbauer, 1991).

Currently, no international center conducts pea breeding and genetic conservation (Upadhyaya et al., 2011) and no single collection predominates in size and diversity. Important genetic diversity collections of *Pisum* with over 2000 accessions are found in national gene banks in at least 15 countries including Poland, China ,Germany and Italy, with many other smaller collections worldwide (Smykal et al.,2011; Coyne et al.,2011).

Conservation of pea germplasm should be scientifically based and internationally coordinated. The key priority is the collection and conservation of the historic land races and varieties of each country in *ex situ* gene banks. The overall goal is to ensure maintenance of variation for adaptation to the full range of agro-ecological environments, end uses (leaves, immature seed and pods, and dry seed), and production systems (He et al., 2008; Bao et al., 2008).

Genetic diversity refers to sum total of genetic variations found in a species or population. Existence of genetic diversity is very essential to meet the present and future crop breeding challenges. It is a prerequisite for the development of improved cultivars with wider adaptability and broad genetic base as well as when selection is to be practiced for improvement. Genetic diversity available in wild *Pisum* species has been poorly exploited. Relatively few genotypes with high degree of relatedness have been used as parents in modern breeding programs, leading to narrower genetic base of cultivated germplasm (Smykal et al., 2011; Ellis et al., 2011). Many studies have been conducted on *Pisum* germplasm collections to investigate genetic and trait diversity.

Genetic variability is prerequisite for crop improvement as it provides raw material to plant breeders to recombine the genes of different characters in same plant for development of desirable variety. To fulfill the demand of increasing population and to produce more food, it would be essential to make better use of a broader range of the world's plant genetic diversity (Farshadfar and Farshadfar, 2008).

1.9 SEED QUALITY AND VIGOR

Seed is considered to be a catalyst of change in agriculture. The Green Revolution in India during the late sixties and seventies and Bt cotton seeds and hybrid maize seeds during the decade of 2000 bears witness to this truth. Efficacy of other agricultural inputs such as fertilizers, pesticides and irrigation is largely determined by the quality of seed. Seed quality is estimated to account for 20-25 percent of productivity. Seed quality (seed viability and vigor) has a profound effect on seedling performance, stand establishment and ultimately economical yield. Sowing of low quality seed (low seed vigor) even at optimum conditions or sowing of high quality seed (high seed vigor) at adverse conditions, both of them usually germinate and emerge over a longer period of time. Maximum seed viability and seed vigor may be achieved if seeds are harvested at the correct stage of maturity. Pea seed should be harvested as soon as possible after attaining an acceptable level of seed moisture.

Seed germination and seedling emergence are affected by many factors such as seed genotype, seed quality (seed viability and seed vigor) and the environmental conditions (moisture and temperature) prevailing during seed germination and subsequent seedling emergence, assuming that the seed is not dormant. Early and uniform germination, adequate seedling emergence and establishment are critical for the commercial growth of pea, because of reduced germination and decreased seedling emergence at low soil temperatures.

Seed vigor refers to the ability and strength of a seed to germinate successfully and produce normal seedling and optimum field stand under both optimum and suboptimal soil conditions and therefore, to maximize yield. Seeds that have high vigor will have high quality. Seed vigor not only influences the productivity but also the storability of seeds. Vigorous seeds can store well, produce uniform stands and develop into vigorous and productive plants. Seeds selected based on high vigor will produce more uniform, vigorous stand of plants resulting ultimately in higher yields per unit area (Tomer and Maguire, 1990). Seed producers use vigor data to monitor seed quality during harvest, drying, conditioning and storage. Breeding programs can also employ vigor tests to develop cultivars with improved seed performance.

The pea has an important status among plants in general and among pulses in particular as it was the solo/main crop selected by Gregor Mendel (1822-1884) for his experiments who tested 28000 pea plants in order to study variation in plants. In recent years considerable emphasis has been made on the improvement of yield of pea including other pulse crops by placing it on the list of national priorities.

But the availability of adequate quality seed is a major hindrance in the way of boosting the India's pea production. A large amount of pea seed remains ungerminated or gets lately germinated or decomposed due to low quality seed used for sowing. The poor and marginal farmers of the country are not able to purchase the quality seeds due to high prices which they are not able to afford. The produce kept by farmers for next year sowing possesses low quality standards like low viability, low germination and low vigor. As a result of low vigorous seeds farmers use the extra seeds (increased seed rate) as against the recommendation of experts which in turn increases the burden (higher costs of production) on shoulders of farmers. Some poor farmers even use the lower seed rates as against the prescribed recommendations.

A good quality seed will be an important factor that will ensure successful crop production and enable the farmer to achieve the full benefits of genetic improvements that take place from time to time through the cultivation of new varieties. High seed and seedling vigor is required for a good stand establishment and successful crop performance in pea.

Seed and seedling vigor is genetically controlled and is modified by the environment (Perry 1973). It is also possible to incorporate this trait in the genetic background of high yielding varieties. Seed and seedling vigor in pea is associated with several quantitative characters (Peterson 1975). The increasing importance of pea in day to day life makes it critical for new pea varieties to possess seed and seedling vigor genes to improve field emergence and ability to compete with weeds. Thus, it is important for breeders to exploit appropriately the genetic differences among pea cultivars for seed and seedling vigor. Since pea is self-pollinated therefore achievement of pure seed is relatively easy but obtaining high vigor seeds needs scientific managements and proper techniques for harvesting, processing, treatment, and storage (Seshu et al., 1987).

The need for modifying the genetic architecture of pea plants suitable for sowing at a lower seed rate and infact under less favorable environmental conditions is greater today than ever, keeping in view the changing environmental conditions due to large scale industrialization and urbanization. To assist in selection of suitable parents with high seed and seedling vigor in hybridization programme, it is important to understand the relative magnitude of genetic variances and the type of gene action involved in the control of vigor traits.

The success of a plant breeding program largely depends on the selection of parents for hybridization and the identification of superior recombinants in the segregating generations. Line x tester cross is a modified form of top cross scheme proposed by Davis in 1927 for inbred evaluation. The line x tester analysis method is used for the screening of favorable parents and crosses and the estimation of their general and specific combining abilities (Kempthorne, 1957; Basbag et al., 2007). In the current research efforts have been made to study inheritance of high quality seed characters from parents to the hybrids through Line x tester studies, in order to improve physiological aspects such as germination capacity and vigor of pea seeds. The pea crop was selected for this study because of the following reasons:

1. It is an important commercial pulse as well as vegetable crop and knowledge of the optimal conditions for germination and seedling establishment is essential for successful cultivation.
2. Pea seed size, shape and color provide easy handling during the limited time available for the research work.
3. Mature seed of high viability is readily available in adequate quantity throughout the year in most parts of the world.
4. The ripple seed is quiescent rather than dormant and germinates rapidly under laboratory conditions.
5. The Pea plant is specifically useful in physiological and genetic studies, as in this research both aspects have been dealt with.
6. In developing countries like India pea is a winter crop which faces seedling emergence and field stand establishment problems, especially in early planting where adverse conditions are prevailed (low temperature and high soil moisture).

Keeping in view, the above mentioned factors in pea, the present studies were undertaken with the following objectives:-

1. To estimate the extent of genetic variability present among the cultivars for seed and seedling vigor traits.
2. To determine the general and specific combining ability of parental effects in various cross combinations using line x tester analysis
3. To study the heterosis among hybrids for traits under study.
4. To study the nature of genetic control of the vigor traits.
5. To study the relationships and path coefficient among the traits under study.
6. To screen the high vigor varieties among different cultivars.

It is hoped that the information so obtained and the material developed from these studies will help to breed better varieties of pea having high seed and seedling vigor in general and the varieties which will be suitable for sowing at a lower seed rate and in adverse environmental conditions, in particular.