Participatory Varietal Selection in Lentil
(*Lens culinaris* M.)

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(2013-A-947-M)

Division of Genetics & Plant Breeding

Faculty of Agriculture

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

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Thesis

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The Faculty of Agriculture
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in partial fulfilment of requirement for the award of the degree of

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2015


Dedicated
To My
Loving Family

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Genetics and Plant Breeding

Certificate – I

This is to certify that the thesis entitled, **"Participatory varietal selection in Lentil (*Lens culinaris* M.)"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Genetics and Plant Breeding),** to the Faculty of Agriculture, **Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Fayaz Rasool (Regd. No. 2013-A-947-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

(Dr. Ajaz Ahmad Lone)
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Division of Genetics and Plant Breeding

Sher-e-Kashmir
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We, the members of the Advisory Committee of **Mr. Fayaz Rasool (Regd. No. 2013-A-947-M)**, a candidate for the degree of **Master of Science in Agriculture (Genetics and Plant Breeding)** have gone through the manuscript of the thesis entitled, **"Participatory varietal selection in Lentil (*Lens culinaris* M.)"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled, **"Participatory varietal selection in Lentil (*Lens culinaris* M.)"** submitted by **Mr. Fayaz Rasool (Regd. No. 2013-A-947-M)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Genetics and Plant Breeding)** was examined and approved by the Advisory Committee and External Examiner on …….

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ABSTRACT

The present study on Lentil (*Lens culinaris* M.) was undertaken during *Rabi* 2013-14 on varietal selection aspect and the trials were laid in order to know the farmers perceptions and constraints for raising the said crop through Participatory Research Approach. Participatory rural appraisal was done in the sixteen locations using a structured questionnaire based on socio-economic attributes, farming systems, production constraints and varietal preferences. The results indicated that there was significant difference among various traits. A grand mother trial comprising of 13 genotypes was laid at DARS Budgam and KVK Pulwama (Malangpora) while as mother trial comprising 13 genotypes was laid at four locations namely Handalbagh and Nagam (Budgam), Wantrag and Chakkissardas (Anantnag). Data was recorded for days to 50% flowering, days to maturity, plant height, pod length, seeds pod^{-1}, seed yield plant^{-1}, seed yield plot^{-1} and 100 seed weight, the data revealed that genotypes were divergent. Participatory varietal selection was done at farmers field and through farm walk when the pods were at maturity stage. During farm walk voting for each genotype was done and preferential score was calculated for each genotype. Genotypes which were selected by farmers almost at every location are; SKUA L 9, VL Masoor 507 and L11 277. Apart from above exercises these genotypes were

evaluated for stability performance across six locations using Eberhert and Russel model (1966). Analysis of variance revealed that all genotypes possessed significant difference for various yield related traits. Estimation of genetic parameters over locations revealed that the environments were significant. Mean squares due to G X E interaction were significant for all the traits. The component analysis of environment (G X E) revealed significant mean squares for all the traits. Mean squares of linear and non-linear components revealed that environments (linear) were significant for all the traits and the significant mean squares for environment + (G x E) for all the traits arose due to environments (Linear) and linear response of the regression of the cultivars to environment. Stability performance of all the traits showed non-significant mean squares for pooled deviation and significant mean squares for pooled deviation could be precise and reliable. The good performance of different traits and their stability across the environment indicated that the genotype SKUA L 9 and VL Masoor 507 were stable for almost all traits.

Key words : Lentil, PRA, PVS, Stability, G x E interaction, Eberhert and Russel model

Signature of Student

Dated:

Signature of Major Advisor

Dated:

Acknowledgement

"Facts without theory is chaos, theory without facts is fantasy"

(A. F. G. Dixon)

In the name of Almighty, "Allah", the most Beneficent and Merciful, Billions of Peace and Blessings be upon Holy Prophet (SAW). I bow in reverence to Almighty for giving me enough courage, patience and success in this venture.

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Place : Shalimar, Srinagar

Dated : ……

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Chapter-1

INTRODUCTION

Lentils are an old world legume and were probably one of the first plant species to be domesticated (Bahl *et al.,* 1993). It is considered to be one of the oldest food crops of mankind that researchers have traced back to 7000-8000 BC (Cubero, 1981). It originated in the fertile Crescent of Mediterranean region and dates back to beginning of agriculture itself. These are mentioned in Egyptian texts dates back to 1085 BC, and were popular crop among Romans and Greeks (Tahir, 1990). Lentils are also mentioned in the first book of Old Testament of Bible (Genesis 27) and is also mentioned in Holy Quran (Second Surah, Al Baqarah; 2:61) as "Manna-o-Salva" which Jews asked Mosses to request Almighty.

Legumes and especially Lentil (*Lens culinaris* M.) are an important food crops in developing countries. Lentil seed is rich source of proteins (up to 28%) in human diets in arid and semi-arid areas of West Asia (Arshad *et al*., 2003). Lentil (*Lens culinaris* M.) is the fourth most important pulse crop in the world. Lentil after beans and chickpea is at the third rank among the grain legumes in Iran in respect of area and production, being 1897 thousand ha and 839.9 thousand tones, respectively (FAO, 2012). It contributes significantly to food, feed and sustainable farming systems and contains high amount of digestible protein (upto 28%), macro-and micronutrients particularly iron and zinc, and vitamins, thus providing nutritional security to consumers. It can be grown on a variety of soils (light loams, alluvial and black cotton soils) and is mostly cultivated under rainfed condition. In India, Lentils are grown over an area of about 1.42 mha with a production of 1.13 mt (*Directorate of Economics and Statistics*). In the last three decades, the area under Lentil has increased by 85 per cent and production by 151 percent, however the productivity has increased only by 34 percent (ICARDA, 2011-12). Lentil has an important role in rainfed cropping systems, providing an alternative to cereal grains (Hamayun *et al.*, 2011). Predominant states for this

crop are Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Jharkhand, Bihar, West Bengal, Assam and Kota Division of Rajasthan.

Lentil straw is a valuable animal feed as it has high digestibility, protein, calcium and phosphorous compared to wheat straw and is highly palatable as well. Lentil seed is a rich source of protein and several essential micronutrients viz., Fe, Zn, β-carotene (Bhatty, 1988). Lentil is grown as a post-rainy season crop mostly under rainfed farming. Substantial area under Lentil in north-eastern states is in rotation with rice, maize, sorghum, cotton, jute, etc. However, it is also grown as an intercrop with wheat, barley, mustard and linseed. The protein fraction of total Lentil nitrogen or the protein nitrogen (PN) is considerably high (4.49 g N/100), representing about 89% of total nitrogen, while the non protein nitrogen (NPN) part accounts for the remaining part, a matter that indicates better nitrogen usability in Lentils than in high NPN foods (El Adway *et al.,* 2003).These characteristics of Lentil proteins make Lentils a source of proteinous edible films that could be used in food industries (Goli *et al.,* 2006). Total carbohydrates represent the major component of Lentil seeds (Lima *et al.,* 2007) with starches occupying most of the carbohydrates mass. Among 23 pulse grains, starch yield from Lentils is second highest, upto 47.14%. Furthermore, Lentils are valuable source of total dietary fibres, with insoluble dietary fibre of approximately 93-99.7% (Murray *et al.,* 2001)

Participatory Plant Breeding (PPB) involves scientists, farmers, and other stakeholders such as consumers, vendors, industry, and rural cooperatives in plant breeding research. It is termed ‘participatory’ because users can have a research role in all major stages of the breeding and selection process. Such ‘users’ become co-researchers as they can help set overall goals, determine specific breeding priorities, make crosses, screen germplasm entries in the pre-adaptive phases of research, take charge of adaptive testing and lead the subsequent seed multiplication process (Sperling and Ashby, 1999). The fundamental rationale for

PPB programs is that joint efforts can deliver more than when each actor works alone.

Breeding programmes across crops has been instrumental in creating a broad spectrum of varieties that have served to enhance the productivity and profitability, resilience to biotic and abiotic stresses as well as quality of produce for industrial use. A critical appraisal of the various National and International breeding programmes reveals that even though the time period for product development has remained more or less same, the product life has declined significantly due to rapid changes in consumer preferences, climatic regimes, pattern of distribution of stresses. Even more disgusting feature of recent plant breeding programmes has been that by the time a variety is developed and ready for release, it loses its relevance resulting in little or absolutely no adoption and subsequent dissemination. A major factor for such a situation is that entire process of variety development is centralised and breeder dictated with little or no involvement of different stakeholders especially the farmers.

Participatory Plant Breeding (PPB) has evolved as viable alternative to the conventional plant breeding that lays more emphasis on the involvement of different stakeholders' right from deciding the varietal specifications, selection of parents through to the selection across segregating generations as well of testing and release of the product. The greater involvement of farmers and other stakeholders ensures that their perceptions are taken care of in order to speed up the rate of adoption. The level of participation may vary depending upon the stage of PPB programme but participation has to be effective at all the stages. Appropriate client orientation mechanism in the form of participatory rural appraisal has to be done in order to generate basic data for varietal specifications and decide the stages and levels of participation of farmers'. Therefore, the present study aimed in the area of participatory plant breeding in Lentil during *Rabi* 2013-14 was undertaken with the following objectives:

1. Understanding farmer’s perceptions and preferences about Lentil varieties through PRA (Participatory Rural Appraisal).
2. Evaluating breeding materials on farmer’s fields using farmer’s selection indices and criteria through mother trials.
3. Analyze Genotype × Location (G×L) interaction to observe a change in magnitude of response across locations.

Chapter – 2

REVIEW OF LITERATURE

Lentil research was initiated in the early 1950s, but was confined to the collection and evaluation of local germplasm (Gowda and Kaul, 1982). A few lines were tested over different locations during the early 1960s, but research virtually stopped because the germplasm was not properly maintained. To halt steady decline in pulse production and attain self-sufficiency, an intensive research effort was launched at Bangladesh Agriculture Research Station (BARI) in 1979 under a research grant project of the International Development Research Center (IDRC), Canada. In the mid-1980s, the Pulses Improvement Program of BARI transformed into the Pulses Research Center (PRC) with its headquarters at Ishurdi Pabna, a representative pulse-growing areas in Bangladesh. The Center established its five regional testing stations, Joydebpur, Jessore, Barisal, Hathhajari and Rajshahi. In late-eighties, the Center became involved in national crop diversification program funded by Canadian International Development Agency (CIDA), Canada. The Center also received a support grant particularly for Lentil improvement research from the Australian Center for International Agricultural Research (ACIAR), Australia, which was implemented by ICARDA. BARI has been working to improve Lentil through conventional breeding approaches. Strategies were adopted to develop high yielding Lentil varieties suitable to the cropping system of short season environment quickly, through introduction or germplasm, particularly from ICARDA. Top priority was given to collection and evaluation of local and exotic Lentil lines. At the same time, work on improved production packages, including pest and disease management, agronomic and cultural management also received due emphasis.

Modern crop varieties bred in various national and international breeding programs have been a driving force for agricultural transformation for improving crop productivity, quality and resilience to biotic and abiotic stresses. However,

the impacts of these high yielding varieties have invariably been more pronounced in high input areas and have seemingly failed to make any dent in low input marginal farming systems. This is largely due to the inherent bottlenecks of low input farming systems such as low socio-economic profile, lack of organized seed sector, lack of affordability/accessibility to resources as well as diversity of farming systems. This has resulted in polarized impact of high yielding varieties in high input favorable systems. Participatory plant breeding has mainly evolved in response to the growing need of addressing the problems faced by poor farmers' in marginal environments with high stress and low yield potential. The major characteristics of conventional plant breeding research that warrants switch over to PPB are:

- Research agenda unilaterally decided by researchers and not the farmer.
- PVS (Participatory Varietal Selection) has been proposed as an option to the problem of fitting the crop, to a multitude of both environment and user preferences (Ceccarelli *et al.*, 1996).
- Breeding research is usually compartmentalized in disciplines and commodities.
- Disproportion between technological interventions developed and those actually reaching farmers' field.
- Plant breeding has not been as successful in marginal environments as in favorable ones.
- Farmers' demand uncommon traits as well as unusual combinations of traits where trade-off seems tricky for a breeder.
- Varietal development is a long process consuming about 15 years by which a variety almost loses its relevance.
- Many varieties released officially but never grown but many unreleased varieties widely grown by farmers.

The work done in the area of Participatory Plant Breeding in Lentil is reviewed in light of the available literature, under following heads:

2.1 Participatory Rural Appraisal

Participatory rural appraisal is an exercise aimed at identification of farmers' constraints pertaining to production, consumption and marketing of crops and is thus a kind of market research, to identify farmers' needs to allow cultivars that are likely to meet their requirements (Joshi and Witcombe, 1998). The preliminary survey of literature reveals very scanty information about the reported results of PRA in Lentil. Adamo (2001) used farmers' social networks as entry points for rural appraisal in Ethiopia for identification of constraints of pulse production and observed that major production constraints prioritized by farmers were moisture stress, poor soil fertility, weeds, soil erosion, pests and diseases and shortage of cultivable land.

Participatory Rural Appraisal conducted in the major Lentil growing states revealed useful information:

1. Improved production technology of Lentil cultivation is not available.
2. Quality seeds of high yielding Lentil varieties not available, and
3. Low-level of knowledge regarding the post-harvest technologies, etc. is available to farming community.

Collinson and Feldstein (1994) made an early attempt to get an insight into farmers' assessment of varietal attributes in beans. They reported that farmers judge bean varieties on the basis of yield, performance under intercropping, performance under adverse conditions, early maturity and grain colour.

Barik *et al*. (1996) presented a study regarding the experiences of participatory research, particularly farmer-led trials, the objective of which was to involve farmers in the decision making at all stages and inculcating their preferences obtained through participatory rural appraisal and the study was also

undertaken by the Krishi Vigyan Kendra, a government organization involved in technology transfer, in Salepali, a complex, diverse and risk prone village in Orissa, India during 1992-93 with the aim of understanding the local agricultural system.

Loader and Amartya (1999) advocated that the rapid acceptance of Participatory Rural Appraisal (PRA) approaches to facilitate the understanding of problems among rural people, and the acknowledged priority for such studies to be sensitive to local conditions, has sometimes meant that such approaches have overlooked opportunities for the appropriate application of relevant techniques and an example was presented from Nepal, where conjoint analysis was used to help farmers to assess their rice variety requirements.

Adamo (2001) used farmers' social networks as entry points for rural appraisal in Ethiopia for identification of constraints of bean production and observed that major production constraints prioritized by farmers were moisture stress, poor soil fertility, weeds, soil erosion, pests & diseases and shortage of cultivable land.

Joshi *et al*. (2001) used Participatory Rural Appraisal technique to establish benchmark information on biophysical, socioeconomic, institutional and farming constraints, as well as farmers' needs, and researchable problems. The general problems of the site was found: the lack of irrigation; hailstone; attacks of red ants in root crops as well as late blight in potato and tomato and white grub in maize, millet and rice; snail attack; labour scarcity during the time of cultivation; blast in rice; animal disease (infertility problem in buffalo and cattle); and scarcity of fodder and forage in summer besides farmers were found demanding high yielding varieties of potato, maize, rice and millet and also the saplings of fodder trees and fruit crops.

Joshi and Witcombe (2002) demonstrated that Farmer Managed Participatory Research (FAMPAR) which used formal survey methods were more

useful for diagnosing reasons for adoption or rejection. It was cost effective and farmer to farmer seed dissemination was higher. Usefulness of approach of FAMPAR in offering choice of new varieties or techniques in a rapid and cost effective manner is well documented (Witcombe *et al.*, 1996). They reported the approach to be instrumental in clarifying the complexities of farming systems by identifying the niches for which farmers adopted technologies. When participatory techniques are appropriately employed in plant breeding they can have an impact by quickly and cost effectively producing much improved varieties. These varieties may be for resource poor farmers in marginal environments who previously where entirely dependent on landraces (Virk *et al.*, 2003; Witcombe *et al.*, 2003) or for farmers in more productive environments where they are dependent on very old varieties.

Chirwa and Phiri (2005) conducted PRA in pulses particularly in bean producing areas in Malawi to identify farmer specifications for selection of varieties and found that farmers' choice of varieties is largely governed by grain colour, cooking time, taste, grain size as well as grain brightness.

Katimgi *et al.* (2011) conducted farmer assessment studies in drought prone areas of Kenya and reported that five production and consumption attributes were rated important by farmers' namely drought tolerance, early maturity, pest resistance and tolerance to poor soils among production attributes while as among consumption attributes farmers rated cooking time, keeping quality, less gas formation, grain size and grain colour were rated as important.

Gichangi *et al.* (2012) underlined the need of assessment of farmers' perceptions and staged that understanding of farmers' technology preference criteria are important considerations in technology generation and dissemination process. In most of the cases, technologies fail to be adopted by farmers' due to mismatch in preference criteria between technology promoters and end users. Such an appraisal exercise should focus on personal, demographic as well as

socio-economic variables, in order to identify farmers' constraints as well as preferred attributes to develop varieties that are likely to be accepted by farmers.

Recently, Asfan *et al.* (2012) conducted extensive rural surveys. They could identify six important attributes out of 32 traits offered for appraisal. The traits included earliness, pod load, pod length, seeds per pod, culinary quality and marketability. The study further revealed that such appraisal studies could identify certain uncommon traits or trait combinations rarely considered by plant breeders in varietal selection such as weed competitiveness, shattering, uniform pod maturity, grain filling etc. Furthermore, PRA can potentially reveal mismatches in the evaluation criteria used by farmers' and breeders to evaluate for the same trait.

Rubyogo *et al.* (2012) outlined the constraint faced in bean production in Ethiopia and reported that inefficient seed delivery system is one of the most important causes of low yield. They emphasized the need to strengthen partnership with various stakeholders and consider consumer and market demands for developing varieties that are likely to be adopted by farmers'. The major constraints identified by them were used of low yield genotypes, Bruchid damage in storage, frequent drought, weeds and low soil fertility.

2.2 Participatory Varietal Selection

Participatory Varietal Selection specifically refers to evaluation of released varieties, pipeline materials, advanced breeding lines, landraces or germplasm accessions on farmers' fields under his management practices. It is essentially a researcher designed and farmer managed trial in which the genotypes targeted for a specific niche are evaluated by farmer using his own selection indices. The PVS trials should not be confused with Minikit trials where advanced breeding lines are tested on farmers' field with recommended package of practices. A number of institutions such as International Centre for Tropical Agriculture (CIAT), International Centre for Agricultural Research in Dryland Areas (ICARDA) and

Pan-African Bean Research Alliance (PABRA) have undertaken PVS in Common bean especially in African countries where it is an important staple crop.

Rosas *et al.* (2003) presented the results of the application of participatory methods for the genetic improvement of beans in two regions of Honduras. The methodology and results obtained from the evaluation and selection activities, from early generation to advanced trials compare the lines selected by conventional and participatory methods, and the trials to estimate the potential of adoption of promising lines, are shown and described. Evaluation and selection criteria used by farmers to choose promising lines and varieties are mentioned. The results are discussed, trying to explain them according to the basic plant breeding principles and practices for the improvement of cultivated plants. Finally, the benefits of participatory plant breeding for farmers are identified, including those that are related to knowledge and skill acquisitions, and the increase on individual and collective capacity to take decisions; as well as the advantages for breeding programs under these participatory approaches.

The research work conducted by Lamin (2005) considered the first participatory varietal selection of common bean to be conducted in a diversity seed fair organized by a farmer from La Jocuma village, a rural Cuban community located in La Palma municipality. In this event, 58 farmers from La Palma participated, and 50 cultivars (commercial, precommercial and landrace) coming from the formal informal seed sectors were presented. The farmers had the opportunity to select up to 5 cultivars of their preference based on their own selection criteria. Generally, it can be confirmed that participatory varietal selection allowed farmers to have access to a wide diversity of cultivars, which contributed to the increase in varietal diversity in participating communities. This type of selection was effective as a strategy to encourage small farmers to adopt and disseminate new cultivars within their communities and in neighboring communities.

Assefa *et al.* (2005) evaluated the potential of Participatory Varietal Selection (PVS) in eastern Ethiopia and reported that PVS can help identification of superior genotypes within a short period of time. Farmers used as many as 40 selection criteria which indicates the complexity of user constraints and needs, but majority of farmers considered yield, tolerance to biotic and abiotic stresses, earliness, marketability, cooking characteristics, seed colour and size and growth habit as important criteria.

Humphries *et al.* (2005) described a PVS programme in Honduras for farmers' led varietal selection for farmers' which revealed that farmers' selected varieties on the basis of grain colour and appearance, grain size, pod length as principal traits. The importance given to these traits by farmers' in hilly regions of Honduras under the reported experiment seasons were likely to be governed by their key role in cash economics. To correct the undesirable traits identified by the farmers' crosses were made using their preferred adapted variety as one of the parents. Many of the lines identified by breeders for hilly areas were actually rejected by farmers' based on their perceived agronomic deficiencies. In fact farmers' did not select any of the stabilized F_6 materials out of these crosses. This implies that it is better to involve farmers' in selection process from an early stage rather than delivering finished products to them.

Singh *et al.* (2007) conducted on-farm PVS trials using released varieties and the segregating materials (F_4-F_7) at different locations and reported that participating farmers' selected varieties/lines based on early maturity, upright plant type and seed colour.

Mulualem *et al.* (2012) used a modification of mother-baby trial system wherein a single season grandmother-mother baby trial system was used to evaluate improved lines on-station and on-farm. In the on-station experiment, material is grown in replicated trial and data generated on quantitative traits

whereas on the farmers' fields, material is grown in un-replicated design using farmers' variety as check and data is generated on farmers' preferences. The selection criteria used by farmers' were plant establishment, stem strength, number of branches, overall performance and seed size. They concluded that farmers' involvement in selection process takes advantage of their potential knowledge of farmers' identifying adapted varieties that are likely to meet their needs. Participatory plant breeding involves scientists, and others, such as consumers, extension activists, vendors, industry, and rural cooperatives in plant breeding research and it is termed participatory because many actors, and especially the users, can have research role in all major stages of the breeding and selection process (Sperling *et al.*, 2001).

2.3 Genotype × Location (G × L) interaction and Stability Studies

The term "stability of genotypes" is central to all types of analyses of G × E interactions especially with reference to plant breeding. Stability has been described in many different ways over the years and there have also been different concepts of stability (Lin *et al.*, 1986).

A genotype does not show stable performance for phenotypic characters under all environments and this variation which arises on account of interaction of genotype with environment is known as G × E interaction. In other words failure of genotype to give the same phenotype performance when tested under different environments is reflection of the genotype environment interaction. It was observed by Yates and Cochran (1938).

Vietra (1973) observed that the French bean exhibits a wide range of variation in growth habit, yield, pod size, color and adaptation to different growth conditions and environments.

Researchers use the terms adaptation, phenotypic stability and yield stability in different ways (Becker and Leon, 1988). Stability in common usage

connotes consistency in performance that would mean minimum variation among environments for a particular genotype (Chahal and Gosal, 2002). Ramagosa and Fox (1993) concluded that if a genotype maintains high yield over a wide range of environments, it is referred to as having general or wider adaptation. On the other hand, if this is true only for a limited range of environments, that genotype has specific or narrow adaptation. The variation in genotypic response from one environment to another is an intrinsic part of a genotypic behavior and without its estimation, assessment of a genotype remains incomplete (Westcott, 1987).

Genotype-environment interaction is always important for plant breeders and genetists. Phenotype is the result of interplay of genotype and its environment. If no genotype environment (G × E) interactions are present, the average difference between genotypes estimated through phenotypic stability in different environments is constant. A specified genotype does not exhibit the same phenotypic characteristics under all environments and different genotypes respond differentially to a specified environment. This variation arising from the lack of correspondence between the genetic and non-genetic effects is known as genotype-environment interaction. These interactions are of major importance to the plant breeder in developing improved genotypes (Kang, 1996). The evaluation of genotype-environment gives an idea of the buffering capacity of the population under study. When genotypes are compared over a series of environments, the rankings usually differ and this may cause difficulty in demonstrating the superiority of any genotype across environments. Stratification of environments has been used effectively to reduce the genotype-environment interaction (Mekbib, 2003).The low magnitude of genotype-environmental interactions indicates consistent performance of a population over different environments.

Tuba and Dogan (2004) analysed fourteen Lentil (*Lens culinaris* Medik) with three checks and 11 Lentil lines developed from previously collected landraces in the Southeast Anatolia of Turkey, were used as experimental

material which were grown in two different locations in 2001/2002. The observations were recorded on days to 50% flowering, days to maturity, biological yield plant^{-1}, seed yield plant^{-1}, plant height, first-pod bearing height, number of branches, pods plant^{-1}, seeds plant^{-1}, 1000 seed weight and grain yield. Analyses of variance revealed considerable variations for all the traits. Grain yield ranged from 158.4 to 235.7 kg/ha. Number of pods per plant ranged from 19.52 to 38.26. The genotype x location interaction was significant, and there were significant differences among genotypes. While genotype BM 760 produced more pods in location 1, genotype BM 500 produced more pods in location 2. Genotype x location interactions for biological yield per plant, seed yield per plant, number of pods plant and number of seeds per plant were significant, and for these characters heritability was found low due to high environmental effects. Days to 50% flowering, days to maturity and seed weight appeared to be useful traits because of high heritability.

Lizana (2006) while studying two varieties of bean to determine the yield stability and the variety Orfeo had a regression coefficient close to 0.9 indicating that it has yield stability, produced very similar yields in all the conditions and Arroz variety had its yield stability below the average with a regression coefficient of 1.84 therefore under favorable conditions its high-yielding variety adapted to high-yield environments. However, small changes in the environment produced large changes in its yield.

Pan (2006) observed highly significant and higher magnitude of linear components of G × E interaction and non-significant and lower magnitude of pooled deviation for days to 50% flowering, plant height and pod length indicated the linear response of the genotypes due to change in environment and their performance could be predicted in respect of these characters.

Dehghani *et al.* (2008) conducted an experiment in 20 rain-fed environments in Iran's Lentil producing areas to characterize genotype by environment (GE) interactions on seed yield of 11 Lentil genotypes. Combined analysis of variance across environments indicated that both environment and GE interactions significantly influenced genotype yield. Several statistical methods and techniques were used to describe the GE interaction and to define stable genotypes in relation to their yield. The results of these different stability methods were variable. However, most showed genotype FLIP 92-12L was stable and genotype Gachsaran was unstable. Genotypes identified as superior differed significantly from local cultivars and can be recommended for use by farmers in semi-arid areas of Iran. Seven stability parameters representing variance component methods and eight stability parameters representing regression models were applied for stability analysis. In the Finlay and Wilkinson (1963) regression model (FW), the observations are regressed on environmental indices defined as the difference between the grand mean of the environments and the overall mean. Eberhart and Russell (1966) further developed FW's regression concept of stability and suggested the use of two stability parameters when describing the performance of one cultivar across a range of environments.

Mohammadi *et al.* (2011) carried out a study to determine the yield performances of ten Lentil genotypes across five locations in Iran for two years from 2003-04 to 2004-05 growing seasons. The goal of this research was to provide biologically meaningful interpretation of genotype environment (GE) interactions and determine stable genotypes by using adjusted Additive Main effect and Multiplicative Interaction (AMMI) model, environmental variance, bi regression coefficient and Wricks ecovalence. After use of adjusted AMMI, F_{GH1} and F_{GH2} indicated only first two IPCA axes of AMMI model were significant at the 0.01 probability level and reminded in the model. The b_i regression coefficient showed genotypes 5 (Flip 92-12L) and 10 (Gachsaran) as the genotypes with the

greatest stability because of their b_i value was significantly lower than 1, but genotype 9 (ILL 6199) possessed average stability due to its regression coefficient near to 1(b_i = 1.02) and can be consider as well adapted genotype across the environments because good mean yield. Genotypes 8 (Flip 96-9L) and 9 (ILL 6199) with the lowest S^2 and W^2_i values (the most stable genotypes) were also within the highest yielding group, and thus performed as the widely adapted genotypes across the test environments. Reliability index of genotypes showed that genotypes 9(ILL 6199) and 1(Flip 96-7L) were the most reliable genotypes and were selected in this research. AMM Stability Value (ASV) parameter of AMMI model correlated significantly and positively with the S^2 and W^2_i stability parameters(r = 0.851**, r = 0.818**, respectively), also two parameters $S^2$and W^2_i showed high and positive correlation (r = 0.997***) and reliability index didn't show any correlation with other parameters. However, genotype 9 with high yield stability in evaluated stability methods, early maturity, high 1000-kernel weight and favorable plant height, was selected for stable and excel genotype in this research.

Lizica *et al.* (2011) while studying seven Lentil genotypes tested for seed yield in two locations of Southern Romania environmental conditions during 2008 and 2009 growing seasons reveled that on the basis of the regression coefficient genotypes Idlib-1, Idlib-2, Idlib-3, Hurani and Kurdi had general adaptability to over environments and genotypes Idlib-4 and Oana were suiTablefor favorable environments. The result of coefficient of variation indicated that the same genotypes were more stable.Among these Idlib-3 genotype was superior for stability and adaptation.

Naser *et al.* (2012) while grouping ten Lentil genotypes that were tested for grain yield in five different environmental conditions, over two consecutive years to classify those genotypes for yield stability found that seed yield of Lentil genotypes ranged from 989.3 to 1.367 kg ha^{-1} and the linear regression coefficient

ranged from 0.75 to 1.18. Further, it was analyzed that the most responsive genotypes with high mean yield genotypes are G2 (1145.3 kg ha^{-1}), G8 (1200.2 kg ha^{-1}) and G9 (1267.9 kg ha^{-1}) and could be recommended as the most favorable genotypes.

Asghar *et al.* (2012) carried out a study to identify the most promising high yielding Lentil genotype for a wide range of environments of Pakistan using 8 stability measures. The experiment consisted of 12 Lentil genotypes grown at 11 locations falling in different agro-ecological zones of Pakistan for 2 years during 2006/07 and 2007/08 under national uniform yield testing. The results revealed that the stability measures for the genotype NARC-06-1 with high mean yield (1140 kg ha^{-1}), regression slope (1.09) close to unity and less statistics of remaining stability measures except high value of R^2 for yield proved to be the best within the pool of studied genotypes and may prove to be a widely adapted high yielding stable variety for a broad spectrum of environments of Pakistan.

Nine common bean genotypes were evaluated by Khalifa (2013) for yield stability to identify the most yield-stable bean lines under limited moisture and temperature stress. The genotypes Bellenber-1, COWU-3-94-9, S/Hashim/98 and the small seeded genotype DB 190-74-1 were to be the most stable can be used to improve common beans.

Abo-Hegazy *et al.* (2013) while investigating to determine the performance and stability of 24 Lentil (*Lens culinaris* M.) genotypes under a wide range of variable environments. The performance of an individual genotype was regressed on the environmental index (deviation of the mean yield at that environment from the overall mean yield of all environments) as outlined by Eberhart and Russell (1966). Accordingly, 4 genotypes (FLIP 96-19L, FLIP 200-18L, PL81-17 and XG88-6-1) were stable for pods $plant^{-1}$ measured by S^2d. For this trait, all genotypes were non-responsive to environmental conditions, except

PL81-17 which may behave positively to pod bearing conditions. For seed yield per plant, only FLIP 95-51L and XG88-17 accessions were significantly unstable measured by S^2d, respectively. It was also found that another two genotypes (FLIP 95-67 L and XG88-17) and one genotype (XG88-1-1) may have performed better for yield per plant under favorable and less favorable environments, respectively. This is due to the significant estimated b which is lesser than unity in the first case and more than one in the second situation.

For genotype-environment interaction significant mean squares have been reported by Rafi *et al.* (2004), Dar *et al.* (2009) and Mwale *et al.* (2009). The variance due to genotypes x environments (linear) was found significant for various traits by Singh *et al.* (2007). The mean squares due to environments were also significant for all the traits indicating the environments selected were random and were different in agro-climatic conditions (Razvi *et al.*, 2011).

Chapter – 3

MATERIALS AND METHODS

The present study on "Participatory Varietal Selection in Lentil (*Lens culinaris* M.)" was undertaken during *Rabi* 2013-14 in two districts of Kashmir valley namely Budgam (34-36˚ E latitude 74˚ N Longitude) and Anantnag (33-34˚ E latitude 74-75˚ N Longitude), which are potential areas for Lentil cultivation. In each district two locations were selected to lay out the trials. The experimental material and methodology used during study are detailed below:

3.1 Experimental material used

The cultivars (Genotypes) used in the present study are given below:

i) VL Masoor 133
ii) VL Masoor 126
iii) VL Masoor 514
iv) VL Masoor 507
v) VL Masoor 129
vi) L11 272
vii) L11 277
viii) SKUA –L 9
ix) L11 279
x) L11 286
xi) L11 299
xii) P2 099
xiii) Shalimar Masoor-1 (Check)

The details of the techniques followed during the course of investigation are as follows:

3.2 Selection of villages

Two districts of Kashmir valley namely Budgam and Anantnag were selected for the proposed study. In each district two locations were selected for

undertaking the study namely Handalbagh and Nagam District Budgam and Wantrag and Chakkiissardas in District Anantnag in consultation with Krishi Vigyan Kendras (KVK) of respective districts. One farmer at each site was identified for laying Mother Trial whileas, the Grandmother Trial (On Station Trial) were laid at Dryland Agricultural Research Station, Budgam and Krishi Vighyan Kendra (KVK), Pulwama.

3.3 Participatory rural appraisal

In order to get an insight into the production constraints and livelihood opportunities with respect to Lentil cultivation in districts of Budgam and Anantnag, participatory rural appraisal was done in the target areas. Participatory Rural Appraisal was conducted prior to laying of trials in the selected sites. Fifty households from each site were surveyed using pre-designed Household Level Questionnaire (HLQ) to identify production constraints as well as the farmers perception about varietal specifications (Annexure-I).

The probing technique was used to derive as much desired information as possible in order to have a thorough insight into the understanding of farmers perspectives, constraints and their willingness to effectively participate in the process of varietal evaluation and genetic resource conservation through large scale use. Flexible approach was used in PRA to derive any other information provided by farmers that was as such not covered within the contents of PRA questionnaire.

3.4 Laying of grand-mother trials

Grandmother trail is a modified form of mother trial laid on the research station under researcher's management to allow optimal trait expression in each test genotype. The trials are laid in replicated design to facilitate in computation of various components of variation. In the present study 13 lines of Lentil were selected out of the germplasm screening on the basis of yield, maturity and disease reaction. The material represented different market classes of Lentil in

order to provide for choice of farmers in light of their preferences and local market value. The material was grown in a replicated trail with replications using Shalimar Masoor-1 variety as check. Each genotype was represented by two lines of 3 metre length with spacing of 30 x 10 cm. Data was recorded from 10 competitive plants from each replication for following morphological, maturity and yield traits:

i) Days to 50% flowering

ii) Days to maturity

iii) Plant height (cm)

iv) No. of pods plant^{-1}

v) Pod length (cm)

vi) Seed yield plant^{-1}(g)

vii) Seed yield plot^{-1} (g)

viii) 100-seed weight (g)

ix) Protein content

x) Disease scoring

3.5 Laying of mother trials

Mother trail consists of preliminary evaluation of a fairly large number of entries (mostly released varieties/pipeline material/advanced breeding lines) in a researcher designed and farmer managed trials. In the present study 13 breeding lines that performed consistently better in station trials were evaluated at four locations namely Wantrag, Chakkiissardas, Nagam and Handalbagh. The experiment was laid in an replicated design with single plot for each genotype of 3×0.5 metre dimensions spaced by 50 cm between plots to allow for farm walk. The trials were designed by scientists but exclusively managed by farmers to provide for real situation assessment of performances of different genotypes.

3.6 From walk and preference score index

At the time of harvest, farm walk was organized at all locations in which farmers were provided with different colours of paper slips to assess the varieties as preferred (positive) or not-preferred (negative). The preference score index was calculated at the farm walk and the varieties designated as preferred or non-preferred were thoroughly discussed with farmers regarding the traits they liked / disliked in those varieties. Preference score index was calculated as given by De-Boef and Thijssen (2007):

$$PI = \frac{\text{No. of positive votes-No. of negative votes}}{\text{Total No. of votes}}$$

The mean preference score was calculated across four locations to arrive at cumulative preference of varieties on the basis of traits specified by them.

3.7 Data collection

The data generated from grand mother and mother trail were collected in two ways:

3.7.1 Quantitative data

The data for following quantitative traits was recorded from ten competitive plants from each replication for various morphological, agronomical, yield and yield attributing traits to study their correlation with farmer's preferential scoring and stability performance over six random environments. Each selected plant were taken at random from each experimental plot in a replication and tagged for recording bio-metrical observations. Mean value of all characters and median values for days to flowering and days to maturity were worked out. Observations were recorded at the appropriate developmental stages of the plant growth as per the descriptors for Lentil. The characters included for the study were:

3.7.1.1 Days to 50% flowering

Recorded as number of days taken from the seed sowing to the emergence of flowering in 50 per cent plants in each experimental plot.

3.7.1.2 Days taken to maturity

Recorded as number of days taken from seed sowing to first pod formation (physiological maturity) on whole plant basis.

3.7.1.3 Plant height

Height of tagged plants was measured in cm as the distance from the ground level to the tip of the plant.

3.7.1.4 No. of pods plant^{-1}

Total number of pods produced by tagged plants were counted of various pickings separately from ten competitive plants and then averaged to get number of pods per plant.

3.7.1.5 Pod length (cm)

Pod length was measured from pedicel upto the tip of pod of ten competitive plants in experimental block and average was taken as a measure of length of pod.

3.7.1.6 Number of seeds pod^{-1}

Seeds were counted from the pods of tagged plants in each experimental plot at maturity and the mean worked out.

3.7.1.7 100-seed weight (g)

From the bulk sample of seeds obtained from the pods of tagged plants, 100 well filled seeds were counted and weighted in g.

3.7.1.11 Seed yield plot^{-1} (g)

The seeds obtained from the net plot were dried for two to three days, cleaned and then weighed in grams.

3.7.1.12 Seed yield plant^{-1}(g)

Total seed yield plant^{-1} was recorded in grams after weighing the total seeds from each tagged plant separately and averaged to a single plant basis.

3.7.2.13 Protein content (%)

Protein content was determined by NIR (Model CROPSCAN 2000G/2000B). Three samples were drawn randomly from each treatment and average worked out for each replication.

3.7.2.14 Disease Scoring (Wilt Incidence)

The disease incidence was scored at three stages of the crop viz; pre-flowering, flowering and maturity stages.

3.8 Statistical analysis

The data recorded on various aspects of grandmother and mother traits including PRA, varietal evaluation and preference score were done as follows :

3.8.1 PRA

The results of PRA were analysed by chi-square test to assess the homogenity of data recorded. The calculated value of χ^2 was tested against tabulated value of χ^2 at degrees of freedom.

3.8.2 Grand mother and mother trail

The data recorded for morphological, maturity and yield traits was analysed by Windostat 9.1 for construction of ANOVA, stability using Eberhart and Russel model (1966).

3.9 Statistical analysis of data

The qualitative data generated through participatory rural appraisal (PRA) was analyzed by using χ^2-test. The data generated from replicated Grandmother and Mother Trials was analyzed through ANOVA.However, wherever, required data transformation was done before such analysis.

3.9.1 Stability analysis

3.9.1.1 Analysis of variance for stability

Linear model of Eberhart and Russell (1966) was followed for analyzing the stability of the 13 genotypes across six locations. The parameters are defined by the following model:

$$Y_{ij} = \mu_i + b_i I_j + S^2_{ij}$$

Where,

Y_{ij} = Mean performance of the i^{th} genotype (i= 1,2,3,……..,g) in the j^{th} environment (j= 1,2,3,……..,n),

μ_i = Overall mean of the i^{th} genotype over all the environments,

b_i = Regression coefficient which measures the response of the i^{th} genotype to varying environments,

I_j = Environmental index obtained as the mean of all varieties at the j^{th} environment minus the grand mean, and

S^2_{ij} = Deviation from regression of the i^{th} genotype in the j^{th} environment

The environmental index for j^{th} environment was calculated as:

$$I_j = \left[\left(\sum_{j-1} Y_{ij}\right) - \left(\sum_{i-1}\sum_{j-1} \frac{Y_{ij}}{gn}\right)\right]$$

Where,

$$\sum_{j-1} I_j = 0$$

Analysis of variance for stability following Eberhart and Russell model (1966)

Source	d.f.	S.S.
Genotypes	(g-1)	$\left[\frac{\sum_i Y^2_i}{n} - \frac{Y^2_{...}}{gn}\right]$
Environment + (Genotype × Environment)	(n-1) + (g-1) (n-1) = g(n-1)	$\left[\frac{\sum\sum_{ij} Y^2_{ij}}{g} = \frac{\sum Y^2_{i.}}{n}\right]$
Environment	(n-1)	$\left[\frac{\sum_j Y^2_{.j}}{g} - \frac{Y^2_{...}}{gn}\right]$
Genotype × Environment	(g-1) (n-1)	$\left[\sum_i \sum_j jY^2_{i,j} - \frac{\sum iY^2_i}{n} - \frac{\sum jY^2_i}{g}\right] + \left[\frac{Y^2_{...}}{gn}\right]$
Environment (linear)	1	$\frac{1}{g}\left[\frac{\left(\sum_{iY} \cdot \sum_{jIj.}\right)^2}{\sum_{jI^2j.}}\right]$
Genotype × Environment (linear)	(g-1)	$\left[\frac{\sum_i \left(\sum_j Y_{ij} I_j\right)^2}{\sum_{jI^2j}}\right]$ – Env. (linear) S.S.
Pooled deviation	g(n-2)	$\sum_i \sum_j = \sum_i \left[\sum_j Y^2_{ij} - \frac{Y^2_i}{n}\right] - \frac{\left(\sum_j Y_{ij}\right)^2}{\left(\sum_j I^2_{j.}\right)}$
Genotype 1	(n-2)	$\left[\sum_j Y^2_{ij} - \frac{Y^2_i}{n}\right] - \left(\sum_j Y_{ij} \cdot \sum_{I_j}\right)^2 \Big/ \sum_j I^2_j$
Genotype g	(n-2)	$\left[\sum_j Y^2_{gj} - \frac{Y^2_g}{n}\right] - \left(\sum_j \sum^2_{rgiJj}\right)^2 \Big/ \sum_j I^2_j$
Pooled error	n(r-1)(g-1)	Pooled replication S.S x genotypes S.S over environments=Me
Total	(gn-1)	$\left[\sum_i \sum_j Y^2_{ij} \quad \frac{Y^2_{...}}{gn}\right]$

Where,

G = Number of genotypes,

N = Number of environments,

R = Number of replications,

I = Environmental index,

Y_{ij} = Basic observations (mean of the i^{th} genotypes over replications in j^{th} environment), and

Me = pooled $\sigma^2 e/r$.

3.9.1.2 Estimation of stability parameters:

a) Regression coefficient (b_i) = $\sum_i Y_{ij} I_j / \sum_j I^2_j$

Where,

$\sum_i Y_{ij} I_j$ = The sum of products i.e. sum of the products of environmental index (I) with the corresponding mean ($\overline{X}$) of that genotype at each location.

$\sum_j I^2_j$ = sum of squares (of environmental index)

b) Mean squares deviation ($S^2 di$) from linear regression

$$= \frac{\sum_j S^2_{ij.}}{n-2} - \frac{S^2 e}{r}$$

Where,

$$\sum_j S^2_{ij} = \left[\sum_j Y^2_{ij} - \frac{Y....}{n}\right] - \frac{\sum_j Y_{ij} I_{j.}}{\sum_j I^2_j}$$

S^2_e = the estimate of pooled error.

3.9.1.3 Test of significance

i) Among the variety means :

H_0 = $g_1 = g_2 = g_3 = \ldots\ldots\ldots = g_n$, the appropriate test is defined as:

F = MS_1 / MS_3

ii) Among varieties for their regression on the environmental index.

H_0 = $B_1 = B_2 = B_3 = \ldots\ldots\ldots = B_g$

$$F = MS_2 / MS_3$$

iii) The genetic differences among genotypes for their regression on environmental index was tested by 't' test.

$$t = \frac{b - 0}{S.E. \quad (b)}$$

Where, S.E. (b) $= \left[\frac{\text{pooled} \quad \text{deviation} \quad \text{MS}}{\sum_j I^2_{j.}} \right]^{\frac{1}{2}}$

i) For the deviation from regression of each genotype.

$F = \left[\sum_j S^2_{ij} / n - 2 \right] / \text{M.S.}$ Pooled error.

ii) The deviation of b_i values from unity was tested as :

$$t = \frac{b - 1}{S.E. \quad (b)}, \text{ for (n-2) d.f.}$$

Where,

$$S.E. \ (b_i) = \left[\sum_{j.} S^2_{ij} \Big/ n - 2 \Big/ \sum_j I^2_j \right]^{\frac{1}{2}}$$

n = number of environments.

Chapter – 4

EXPERIMENTAL FINDINGS

The present investigation entitled "Participatory Varietal Selection in Lentil (*Lens culinaris* M.)" through mother trial evaluation system in Kashmir valley" was carried out for evaluation of released varieties, pipeline materials, advanced breeding lines, landraces or germplasm accessions on farmers' fields under his management practices and produce farmer acceptable cultivars more effectively. The genotypes (VL Masoor 133,VL Masoor 126, VL Masoor 514, VL Masoor 507, VL Masoor 129, L11 272, L11 277, SKUA L 9, L11 279, L11 286, L11 299, P2-099 and Shalimar Masoor-1 as a check) were evaluated to target for a specific niche by farmers using his own selection indices Further the genotypes were assessed for the stability across six test locations/environments to character performance to characterize the nature of genotype × location interaction for yield related and other traits. The genotypes were evaluated in a Randomized Complete Block Design (RCBD) with three replications across all six random environments representing mountain agroecology of Kashmir valley situated between 2000 to 2300 m. a.m.s.l. Before laying out the trials Participatory Rural Appraisal (PRA) was conducted.

The results obtained, after subjecting the data (qualitative as well as quantitative) to parametric statistical tests, and inferences drawn thereafter, regarding the farmers perception preferential scoring and stability parameters of genotypes are described in the present chapter under the following heads:

4.1 Understanding farmers' perceptions through Participatory Rural Appraisal (PRA)

4.2 Calculation of preferential scoring of different genotypes; and

4.3 Estimation of stability parameters and identification of suitable genotypes.

4.1 Understanding farmer's perceptions through Participatory Rural Appraisal (PRA)

Based on the feedback generated during participatory rural appraisal, the perception of farmers regarding different traits of Lentil was worked out. The chi-square (χ^2-test) analysis (Table-1.1) revealed that the farmers preference was highly significant for most of the traits. Farmers perception for Lentil can be discussed under following Subtitles:

4.1.1 Background Information

There were 13 tailor made questions in the questionnaire and the questions were asked in vernacular language and were filled in by the researcher himself after listening to the replies (Table-1). The questionnaire was carefully designed with an aim of dissecting all relevant facets involved in Lentil cultivation.

4.1.1.1 Crop grown for the purpose

Household Level Questionnaire (HLQ) conducted during *rabi* 2013-14 revealed that most of the farmers across all locations grow Lentil for *dal* purpose.

4.1.1.2 Source of seed (Farmer own seed versus Market + Institution)

Regarding the source of source of seed, significant number of the selected farmers reported that they use their own seed for production of Lentil. More than half (60.72%) of total farmers use their own saved seed and 25.29 per cent get it through market while as Institutes contributing 13.99 per cent.

4.1.1.3 Cropping System (mixed Crop versus Inter-crop+ sole crop)

Lentil is being widely practiced as mixed cropping, however at location, Chakki issardas (Anantnag) a good number of farmers (30.23%) were practicing sole cropping.

4.1.1.4 Irrigation system (Rainfed versus assured)

Data of farming practice across sixteen locations revealed that when farmers were asked about the source of irrigation system, it was found that crop

was mostly grown under rain-fed conditions, however 44.74 percent of farmers of Chadoora district Budgam grow Lentil under assured irrigated.

4.1.1.5 Production constraints (Low yield versus Disease)

In this regard farmers were asked whether it was low yielding varieties or diseases as major constraints in Lentil production. The comparison between the two data revealed that the low yielding varieties was used by the farmers a significant factor in limiting Lentil crop production and diseases ranked second as production constraints. The low yielding varieties are the major production constraints and observed data in this regard revealed that low yield was main problem in more than 67 percent of farmers.

4.1.1.6 Maturity (Earliness versus uniform maturity)

One of the most important traits in Lentil crop is maturity fitness. From Table-1.1, chi-square value revealed there is a significant difference in earliness and uniform maturity. Earliness was more preferred as farmers across these locations take 2 to 3 different crops during optimal cultivation years.

4.1.1.7 Varietal preference of color of seed (Yellowish-Red range versus Black+Grey)

Regarding color of seed farmers favoured yellow-red coloured varieties as compared to other types.

4.1.1.8 Seed size (Bold versus Small)

Farmers almost across all locations like bold seed Lentils and this trait scored highest percentage in Devipora (Anantnag) followed by Kawarigam (Anantnag) with a percentage of 78.95 and 78.05 respectively.

4.1.1.9 Cooking time (Less time vs More time)

The perceptions of farmers regarding cooking time revealed that the significant number of farmers preferred that Lentil variety which takes less time to cook.

Table-1: Participatory Rural Appraisal in lentil (*Lens culinaris Medik.*) for various traits across 16 villages

Locations	Respondents	Source of seed			Cropping system			Irrigation system		Production constraints		Maturity	
		Farmers own seed	Institution	Market	Mixed crop	Sole crop	Intercrop	Rainfed	Assured Irrigation	Low yield	Disease	Earliness	Uniform maturity
Kehribal (Anantnag)	44	33 (75.00)	4 (9.09)	7 (15.09)	27 (61.36)	10 (22.72)	7 (15.90)	29 (65.90)	15 (34.09)	29 (65.9)	15 (34.09)	31 (70.45)	13 (29.54)
Chakiisssardas (Anantnag)	43	29 (67.44)	5 (11.60)	9 (20.93)	25 (58.13)	13 (30.23)	5 (11.60)	28 (65.18)	15 (34.88)	31 (72.09)	12 (27.90)	33 (76.74)	10 (23.25)
Chattisinghpora (Anantnag)	37	29 (78.37)	3 (8.10)	5 (13.51)	22 (59.45)	7 (18.91)	8 (21.62)	26 (70.27)	11 (29.72)	29 (78.37)	8 (21.62)	27 (72.97)	10 (27.02)
Wantrag (Anantnag)	46	30 (65.21)	3 (6.52)	13 (28.26)	30 (65.21)	4 (8.69)	12 (26.08)	30 (65.21)	16 (34.78)	35 (76.08)	11 (23.91)	30 (65.21)	16 (34.78)
Devipora (Anantnag	38	26 (68.42)	4 (10.53)	8 (21.05)	23 (60.53)	6 (15.79)	9 (23.68)	24 (63.15)	14 (36.84)	29 (76.32)	9 (23.68)	24 (23.15)	14 (36.84)
Kawarigam (Anantnag)	41	25 (60.98)	6 (14.63)	10 (24.39)	24 (58.54)	8 (19.51)	9 (21.95)	26 (63.41)	15 (36.58)	28 (68.29)	13 (31.70)	26 (63.41)	15 (36.58)
Hardutooru (Anantnag)	40	24 (60.00)	5 (12.50)	11 (27.50)	25 (62.50)	9 (22.50)	6 (15.00)	25 (62.50)	15 (37.50)	25 (62.50)	15 (37.50)	23 (57.50)	17 (42.50)
Akura (Anantnag)	42	23 (54.76)	7 (16.67)	12 (28.57)	27 (64.29)	11 (26.19)	4 (9.52)	24 (57.14)	18 (42.85)	27 (64.29)	15 (35.71)	29 (54.76)	13 (30.95)
Nagam (Budgam)	45	22 (48.89)	8 (17.78)	15 (33.33)	31 (68.89)	7 (15.56)	7 (15.56)	28 (62.22)	17 (37.77)	26 (57.78)	19 (42.22)	33 (73.33)	12 (26.66)
Handalbagh (Budgam)	36	25 (69.44)	3 (8.33)	8 (22.22)	22 (61.11)	6 (16.67)	8 (22.22)	24 (66.66)	12 (33.33)	22 (61.11)	14 (38.88)	25 (69.44)	11 (30.55)
Nagam (Budgam)	39	16 (41.03)	9 (23.08)	14 (35.90)	26 (66.66)	6 (15.38)	7 (17.94)	28 (71.79)	11 (28.21)	24 (61.54)	15 (38.46)	27 (69.23)	12 (30.76)
Panzan (Budgam)	46	19 (41.30)	11 (23.91)	16 (34.78)	30 (65.21)	10 (21.73)	6 (13.04)	31 (67.39)	15 (32.61)	30 (65.22)	16 (34.78)	32 (69.56)	14 (30.43)
Chadoora (Budgam)	38	20 (52.63)	7 (18.42)	11 (28.95)	25 (65.78)	9 (23.68)	4 (10.52)	21 (55.26)	17 (44.74)	28 (73.68)	10 (26.31)	26 (68.42)	12 (31.57)
Ganjbagh (Budgam)	35	22 (62.86)	4 (11.43)	9 (25.71)	20 (57.14)	6 (17.14)	9 (25.71)	22 (62.86)	13 (37.14)	23 (65.71)	12 (34.28)	24 (68.57)	11 (31.42)
Wathoora (Budgam)	33	20 (60.61)	5 (15.15)	8 (24.24)	18 (54.55)	7 (21.21)	8 (24.24)	19 (57.58)	14 (42.42)	22 (66.67)	11 (33.33)	25 (75.75)	8 (24.24)
Cicipora Beerru (Budgam)	37	24 (64.86)	6 (16.22)	7 (18.92)	22 (59.45)	8 (21.62)	7 (18.91)	24 (64.86)	13 (35.14)	25 (67.57)	12 (32.43)	28 (75.67)	9 (24.32)

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Table-1 contd…

Locations	Respondents	Seed colour			Seed size		Cooking time		Abiotic stress	
		Yellowish to Red range	Black	Grey	Bold	Small	Less time	More time	Drought tolerance	Recovery from drought
Kehribal (Anantnag)	44	34 (77.27)	7 (15.91)	3 (6.82)	28 (63.64)	16 (36.36)	31 (70.45)	13 (29.55)	32 (72.27)	12 (27.27)
Chakiisssardas (Anantnag)	43	32 (74.42)	6 (13.95)	5 (11.63)	25 (58.14)	18 (41.86)	29 (67.44)	14 (32.56)	34 (79.07)	9 (20.93)
Chattisinghpora (Anantnag)	37	29 (78.38)	4 (10.81)	4 (10.81)	28 (75.68)	9 (24.32)	27 (72.97)	10 (27.03)	31 (83.78)	6 (16.22)
Wantrag (Anantnag)	46	34 (73.91)	8 (17.39)	4 (8.70)	29 (63.04)	17 (36.96)	30 (65.22)	16 (34.78)	28 (60.86)	18 (39.13)
Devipora (Anantnag)	38	30 (78.95)	5 (13.16)	3 (7.89)	30 (78.95)	8 (21.05)	29 (76.32)	9 (23.68)	29 (76.31)	9 (23.68)
Kawarigam (Anantnag)	41	33 (80.49)	5 (12.20)	3 (7.32)	32 (78.05)	9 (21.95)	28 (68.29)	13 (31.71)	30 (73.17)	11 (26.83)
Hardutooru (Anantnag)	40	29 (72.50)	7 (17.50)	4 (10.00)	26 (65.00)	14 (35.00)	24 (60.00)	16 (40.00)	27 (67.50)	13 (32.50)
Akura (Anantnag)	42	31 (73.81)	6 (14.29)	5 (11.90)	29 (69.05)	13 (30.95)	25 (59.52)	17 (40.48)	28 (66.67)	14 (33.33)
Nagam (Budgam)	45	29 (64.44)	9 (20.00)	7 (15.56)	31 (68.89)	14 (31.11)	27 (60.00)	18 (40.00)	25 (55.56)	20 (44.44)
Handalbagh (Budgam)	36	24 (66.67)	7 (19.44)	5 (13.89)	21 (58.33)	15 (41.67)	24 (66.67)	12 (33.33)	21 (58.33)	15 (41.67)
Nagam (Budgam)	39	27 (69.23)	8 (20.51)	4 (10.26)	26 (66.67)	13 (33.33)	29 (74.36)	10 (25.64)	23 (58.97)	16 (41.03)
Panzal (Budgam)	46	36 (78.26)	5 (10.87)	5 (10.87)	31 (67.39)	15 (32.61)	28 (60.87)	18 (39.13)	25 (54.35)	21 (45.65)
Chadoora (Budgam)	38	23 (60.53)	9 (23.68)	6 (15.79)	27 (71.05)	11 (28.95)	25 (65.79)	13 (34.21)	21 (55.26)	17 (44.74)
Ganjbagh (Budgam)	35	17 (48.57)	10 (28.57)	8 (22.86)	26 (74.29)	9 (25.71)	24 (68.57)	11 (31.43)	23 (65.71)	12 (34.29)
Wathoora (Budgam)	33	24 (72.73)	6 (18.18)	3 (9.09)	25 (75.76)	8 (24.24)	21 (63.64)	12 (36.36)	19 (57.58)	14 (42.42)
Cicipora Beerru (Budgam)	37	20 (54.05)	11 (29.73)	6 (16.22)	23 (62.16)	14 (37.84)	20 (54.05)	17 (45.95)	21 (56.76)	16 (43.24)

Values within parenthesis are percentages

Table 1.1: District-wise Participatory Rural Appraisal in lentil (*Lens culinaris* M.) for various traits

Districts	Respondents	Source of seed			Cropping system			Irrigation system		Production constraints			
		Farmers own seed	Institution	Market	Intercrop	Sole crop	Mixed crop	Rainfed	Assured Irrigation	Low yield	Disease	Earliness	Uniform maturity
Anantnag	331	219 (64.22)	37 (10.85)	75 (21.99)	203 (59.53)	68 (19.94)	60 (17.59)	212 (62.17)	119 (34.89)	233 (68.32)	98 (28.73)	223 (65.39)	108 (31.67)
Budgam	309	168 (54.36)	53 (17.15)	88 (28.47)	194 (62.67)	59 (19.09)	56 (18.12)	197 (63.75)	112 (36.24)	200 (64.72)	109 (35.27)	220 (71.19)	89 (28.80)
Chi square value			29.11			26.78		27.49		45.02		50.97	
p value (≤ 0.05)			0.007			0.894		0.930		0.126		0.295	

Values within parenthesis are percentages

Contd…

Table 1.1 contd…

Districts	Respondents	Seed colour			Seed size		Cooking time		Abiotic stress	
		Yellowish/ Red color range	Black	Grey	Bold	Small	Less time	More time	Drought tolerance	Recovery from drought
Anantnag	331	252 (73.90)	48 (14.07)	31 (9.36)	227 (66.56)	104 (30.49)	223 (65.39)	108 (32.62)	239 (70.08)	92 (27.79)
Budgam	309	200 (64.72)	65 (21.03)	44 (14.23)	210 (67.96)	99 (32.03)	198 (64.07)	111 (35.92)	178 (57.60)	131 (42.39)
Chi square value			64.89		48.09		36.81		40.89	
P value (≤ 0.05)			0.007		0.866		0.380		≤ 0.0001	

Values within parenthesis are percentages

4.1.1.10 Abiotic Stress (drought tolerance versus recovery from drought)

Among abiotic challenges drought tolerance was felt by the significant proportion of the selected farmers. The comparison of drought tolerance versus recovery from drought revealed that former was felt by 65.13 per cent and later by less than 34.83 per cent respectively.

The chi square (χ^2-test) analysis of participatory rural appraisal (PRA) (Table1.1) revealed that most of farmers across all sixteen locations cultivate Lentils for dal purpose. Further, it was also revealed that farmers use their own seed for cultivation under rain-fed conditions and mostly practiced it as mixed crop. Chi square value also revealed that low yield was major production constraint and yellow-red coloured bold shaped seed were preferred by Lentil cultivators across all the locations. Further, Chi square value also revealed that the varieties that required less time to cook were most preferred.

4.2 Calculation of preferential scoring of different genotypes

Participatory varietal selection was carried out in two districts, by selecting two villages in each district. Farm walk was done when pods were at ripened stage. Farm walk is an exercise done by research scientists and farmers to know perception of farmers about different genotypes and to select genotypes of their choice. During farm-walk each farmer was given two cards to vote for their preferential variety (red card for preferred genotype and pink for non-preferred genotype).

Evaluation of Mother Trials through farmer's preferential ranking was carried out at four locations. At the time of pod maturity Focal Group Discussions (FGD) were used to evaluate the varieties. There was very good response from the farmers who not only cooperated while laying out the trials in their area but actively participated in preferential ranking of the varieties through voting. At village Handal Bagh (Budgam) (Table-2) highest preferential scoring i.e. lowest rank value was recorded on SKUA L 9 (1) and L 11 277(1) followed by VL

Masoor 507 (3), Shalimar Masoor 1(4), and L11 286(5). The lowest preference was recorded for VL Masoor 514(13). Similarly at village Nagam in Budgam district (Table-2.1) maximum scoring was recorded for SKUA L 9 (1) followed by VL Masoor 507 (2), L-11 277 (3) and Shalimar Masoor 1(3) and at village Wantrag in Anantnag district (Table-2.2) SKUA L 9 (1), VL Masoor 507 (2), L11 286 (3), Shalimar Masoor 1 (4) received maximum number of votes and was followed by L 11 277 (5), L 11 299 (5) and P2 099 (7). The maximum farmer's votes were recorded for SKUA L 9 (1) followed by VL Masoor 507 (2), P2 099 (3), VL Masoor 133(4), L 11 277 (6), L11 279(7) and Shalimar Masoor-1 (8) at village Chakkiissardas in Anantnag (Table-2.3).

Table-2.4 gives the picture of rank summation preferential data for different test entries as collected from four mother trials. Lowest cumulative rank that is the most preferred variety was recorded on SKUA L 9 with mean preference rank of 1.00, VL Masoor 507 identified as second best (2.25) followed by L-11 277 (4.5), Shalimar Masoor-1 (4.75). Table-2.4 clearly shows that VL Masoor 126, L11 286, L11 299 and L11 279 were statistically at par in term of rank summation index and mean preference ranking.

The feedback from most of the farmers revealed that the reasons for the preference for a genotype were related to many traits including early maturity, good plant height (45-59 cm) and also disease free crop.

4.2.1 Mean performances

4.2.1.1 Mean performance of genotypes

The mean performance in respect of traits studied for varieties is presented in Appendix-II.

4.2.1.2 Days to 50% flowering

Genotype that flowered the earliest was L 11 279 (148.225) and the one that flowered last was SKUA L 9 with highest number of days to flower (164.773) and the average of all genotypes was (162.344).

Table 2: Evaluation form of mother trials using preferential analysis

State	Jammu and Kashmir		Village	
District	Budgam		Handal Bagh	
	Total number of farmers (16)			
Genotypes↓	Positive votes	Negative votes	Preference Score	Rank
SKUA L 9	15	1	0.875	01
VL Masoor 507	14	2	0.750	03
L11 277	15	1	0.875	01
VL Masoor 129	9	7	0.125	06
VL Masoor 126	5	11	-0.375	08
L11 272	1	15	-0.875	11
L11 279	3	13	-0.625	09
L11 286	11	5	0.375	05
L11 299	8	8	0.000	12
VL Masoor 514	8	8	0.000	13
P2 099	7	9	-0.125	07
VL Masoor 133	2	14	-0.750	10
Shalimar Masoor-1 (Check)	13	3	0.625	04

Table 2.1: Evaluation form of mother trials using preferential analysis

State	Jammu and Kashmir		Village	
District	Budgam		Nagam	
	Total number of farmers (16)			
Genotypes↓	Positive votes	Negative votes	Preference Score	Rank
SKUA L 9	16	0	1.000	01
VL Masoor 507	12	04	0.500	02
L11 277	11	05	0.375	03
VL Masoor 129	08	08	0.000	12
VL Masoor 126	05	11	-0.375	07
L11 272	07	09	-0.125	05
L11 279	06	10	-0.250	06
L11 286	08	08	0.000	12
L11 299	02	14	-0.750	08
VL Masoor 514	02	14	-0.750	08
P2 099	01	15	-0.875	10
VL Masoor 133	0	16	-1.000	11
Shalimar Masoor-1 (Check)	11	05	0.375	03

Table 2.2: Evaluation form of mother trials using preferential analysis

State	Jammu and Kashmir		Village	
District	Anantnag		Wantrag	
	Total number of farmers (16)			
Genotypes↓	Positive votes	Negative votes	Preference Score	Rank
SKUA L 9	16	0	1.000	01
VL Masoor 507	12	4	0.500	02
L11 277	6	10	-0.250	08
VL Masoor 129	4	12	-0.500	09
VL Masoor 126	1	15	-0.875	11
L11 272	09	07	0.125	05
L11 279	08	08	0.000	12
L11 286	11	5	0.375	03
L11 299	09	07	0.125	05
VL Masoor 514	3	13	-0.625	10
P2 099	7	9	-0.125	07
VL Masoor 133	08	08	0.000	12
Shalimar Masoor-1 (Check)	10	06	0.250	04

Table 2.3: Evaluation form of mother trials using preferential analysis

State	Jammu and Kashmir		Village	
District	Anantnag		Chakki issardas	
	Total number of farmers (16)			
Genotypes↓	Positive votes	Negative votes	Preference score	Rank
SKUA L 9	14	02	0.750	01
VL Masoor 507	13	03	0.625	02
L11 277	09	07	0.125	06
VL Masoor 129	0	16	-1.000	11
VL Masoor 126	03	13	-0.625	10
L11 272	11	05	0.375	04
L11 279	07	09	-0.125	07
L11 286	08	08	0.000	13
L11 299	04	12	-0.500	09
VL Masoor 514	0	16	-1.000	11
P2 099	12	04	0.500	03
VL Masoor 133	06	10	0.375	04
Shalimar Masoor-1 (Check)	10	06	-0.375	08

Table-2.4 : Cumulative average ranks of preferential score of genotypes over four locations

Genotypes	Individual Ranks				Cummulative rank	Average Ranks	Pooled preference score
	Handal bagh (Budgam)	Nagam (Budgam)	Wantrag (Anantnag)	Chakki issardas (Anantnag)			
SKUA L 9	01	01	01	01	4	1.00	3.625
VL Masoor 507	03	02	02	02	9	2.25	2.375
L11 277	01	03	08	06	18	4.50	1.125
VL Masoor 129	08	12	09	11	40	10.00	-1.375
VL Masoor 126	10	07	11	10	38	9.50	-2.250
L11 272	13	05	05	04	27	6.75	-0.500
L11 279	11	06	12	07	36	9.00	-1.000
L11 286	07	12	03	13	35	8.75	0.750
L11 299	14	08	05	09	36	9.00	-1.125
VL Masoor 514	14	08	10	11	43	10.75	-2.375
P2 099	09	10	07	03	29	7.25	-0.625
VL Masoor 133	12	11	12	04	39	9.75	-1.375
Shalimar Masoor-1 (Check)	04	03	04	08	19	4.75	0.875

4.2.1.3 Days to maturity

Genotype that matured first was L 11 299 (190.669 days) and that which matured at last was L 11 277 with highest number of days to mature (197.223). The average of all genotypes in each environment revealed that E_1 had lowest value for days to maturity (195.410) and E_6 had highest days to maturity (202.333).

4.2.1.4 Plant height (cm)

Highest value for plant height in individual environments was recorded for genotype VL Masoor 507 (44.974 cm), whereas lowest value for height was recorded for VL Masoor 129 (29.029 cm). The average of all the genotypes in each environment revealed that E_1 the highest value of plant height being (39.500 cm) and E_5 had the lowest (32.900 cm).

4.2.1.5 No. of pods plant^{-1}

Highest value for number of pods per plant was recorded for genotype L11 277 (58.083), whereas lowest value was recorded for genotype VL Masoor 133 (47.098). The average of all varieties in each environment revealed that E_1 had highest number of pods per plant (57.291) and E_6 had the lowest number of pods per plant (48.092).

4.2.1.6 Pod length (cm)

Pod length in individual environments was highest for the genotype SKUA L-9 (1.430 cm), whereas it was lowest for P2 099(1.084cm).The average of all environments revealed that E_1 had the highest value of pod length (1.279 cm) and E_5 had the lowest (1.168 cm).

4.2.1.7 Number of seeds pod^{-1}

The highest number of seeds was found in L11 277 (2.000) and the lowest in L11 279 (1.471).The average number of seeds per pod across all environments was 1.741.

4.2.1.8 100-seed weight (g)

The highest 100-seed weight was found in genotype SKUA L 9 (4.806 g) and the lowest in VL Masoor 129 (2.423 g). The average 100-seed weight of all genotypes across environments was found highest in environment E_2 (3.4305 g) and the lowest in environment E_6 (3.321 g).

4.2.1.0 Seed yield plant^{-1}(g)

Genotype SKUA L 9 recorded the highest seed yield per plot (3.939 g), and genotype L11 272 recorded lowest (2.189 g). The average seed yield per plant of all genotypes across environments was found to be highest in environment E_1 (3.274 g) and the lowest in environment E_6 (2.748 g).

4.2.1.10 Seed yield plot^{-1} (g)

Genotype SKUA L 9 recorded the highest seed yield per plot (133.926 g), and genotype L11 272 recorded lowest (74.426 g). The average seed yield per plot of all genotypes across environments was found to be highest in environment E_1 (1091.44 g) and the lowest in environment E_6 (916.28 g).

4.2.1.11 Protein content (%)

The highest protein content was found in SKUA L 9 (26.374%) and the lowest in VL Masoor 133 (20.598%). The average of protein content across all environments was 22.251 per cent.

4.3 Estimation of stability parameters and identification of suitable genotypes

Based on the performance of genotypes, the stability performance of different traits was worked out. Analysis of variance (ANOVA) for stability performance of different genotypes across six random environments (Table-3) revealed that mean squares due to genotypes (cultivars) were highly significant for all the traits viz., days to 50% flowering, plant height (cm), days to maturity, pod length (cm), number of seeds pod^{-1}, No. of pods plant^{-1}, seed yield plot^{-1} (g),

1000-seed weight (g) and protein content (%). The genotypes, thus, selected were divergent and possessed significant genetic variation for all these traits. The random environments selected revealed significant differences for all the traits, confirming that the selected environments were variable and random, and influenced the expression of traits selected for stability studies.

Mean squares arising due to genotypes x environments (G × E interaction) revealed significant differences for all the traits except protein content, revealing that the genotypes were having, by and large, significant differential response to the changing environments. Component analysis of the environments + (genotype × environment) interaction [E + (G × E)] was significant for all the traits. Partitioning of this variation into linear and non-linear components revealed that the mean squares due to environments (linear) were highly significant for all the traits except 100 seed weight. The significance is probably due to sampling error and/or average linearity of the environments as compared to individual environments. The significant mean squares confirmed that the environments were random and different and they exercised influence on the expression of a trait. This variation could be attributed to have arisen due to linear response of the regression of the genotypes to the environment. The mean squares due to G × E (linear) were significant for all the traits revealing that behavior of the genotypes could be predicted more precisely over environments. This can be efficiently used for identifying the suitable genotypes for a particular area. Mean square due to environment (linear) component was found to be non-significant for 100-seed weight, however for all the other characters the component was observed implied that means of genotypes varied considerably at different locations.

Table-3: Analysis of variance for stability of different traits in selected Lentil genotypes across 6 random environments

Source of variation	d.f	Mean squares								
		Days to 50 % flowering	Days to Maturity	Plant height	No. of pods per plant	Pod length	Seeds per pod	Seed yield per plot	Protein content	100 seed weight
Genotypes	12	63.953**	6.542**	177.967**	141.069**	0.075*	0.127**	0.013**	27.783**	4.716 **
Environment + (Genotypes × Environment)	65	11.630**	6.812**	13.052**	15.014**	0.003*	0.011**	0.017**	0.013*	0.014 **
Environment	5	137.670**	82.443**	91.102**	142.726**	0.032*	0.021**	0.006**	0.058**	0.020 **
Genotypes × Environment	60	1.127**	0.509**	6.548**	4.371*	0.001*	0.143*	0.014**	0.010	0.013 *
Environment (linear)	1	688.349**	412.216**	455.511**	713.629**	0.159**	0.106**	0.012*	0.288**	0.099
Genotype × Environment (linear)	12	2.352**	1.484**	22.195**	10.335**	0.002*	0.06*	0.015**	0.014*	0.016**
Pooled deviation (non-linear)	52	1.225*	0.245*	2.434**	2.659*	0.002**	0.010*	0.018**	0.008*	0.012**
Pooled error	144	1.023	0.103	1.314	1.245	0.0001	0.0005	0.04	0.003	0.006

* Significant at p≤0.05; **Significant at p≤0.01

Significant pooled deviation component for all the traits suggested that the performance of different genotypes fluctuated significantly from their respective linear path of response to environments. Predominance of linear component of (genotype × environment) to non-linear component (pooled deviation) suggested that genotype × environment interaction was predominantly the outcome of linear function of genotype × environment and performance can be predicted with great precision across the environments.

4.3.1 Estimation of stability parameters and identification of stable genotypes (as per Eberhart and Russel's Model)

Estimation of stability parameters for different traits viz. days to 50 per cent flowering, days to maturity, plant height, pods plant^{-1}, pod length, number of seeds pod^{-1}, 100 seed weight, seed yield plot^{-1} and protein content across six random environments are presented in the Table-3. The stability parameters estimated were mean of the trait ($\overline{X}$), linear regression (b_i), mean square deviation from regression (S^2d_i), where $\overline{X}$ provides a measure of the performance of a variety as compared to other entries, the b_i and S^2d_i values are the measure of the G × E interaction. The components S^2d_i measures predictability and the component b_i measures the stability. In general, if G × E is non interaction significant or where this G × E interaction is either linear or predominantly linear as compared to its non-linear component, the predict-ion of stability of a genotype over environments become more reliable. As per the Eberhart and Russel's model of stability, the component S^2d_i measures predictability and b_i the stability. Stability of a genotype can be predicted more precisely if G × E interaction and S^2d_i value are non-significant.

4.3.1.1 Days to 50% flowering

Estimation of stability parameter for the number of days to 50 per cent flowering are presented in Table-4. The mean value ranged from 148.225 (L11 279) to 164.773 (SKUA L 9) and with overall mean ($\overline{X}$) of 162.344 days. This parameter revealed non-significant deviation from regression (S^2d_i) for all

Table-4: Stability parameters for days to 50 per cent flowering and days to maturity

Genotypes	Days to 50 % flowering			Days Taken to Maturity		
	Mean($\overline{X}$)	b_i	S^2d_i	Mean ($\overline{X}$)	b_i	S^2d_i
SKUA L 9	164.773	0.982*	1.582	199.331	1.092	-2.457
VL Masoor 514	158.946	3.940	-5.397	192.163	-0.837	-4.532
VL Masoor 129	158.777	0.975	-2.162	193.774	-1.382	-11.035
VL Masoor 126	157.500	-1.085	-12.264	192.443	2.124	-9.548
L11 272	152.501	2.044	-10.466	195.442	-1.052	-7.602
L11 279	148.225	-0.832	-9.871	192.830	1.113	-8.621
L11 277	160.002	0.981*	0.134	197.223	0.852	-0.362
L11 286	155.552	1.023	-17.440	191.552	-4.103	0.583
L11 299	159.500	-1.367	-9.230	190.669	4.711	0.602
VL Masoor 507	162.058	0.821	2.715	196.382	0.971	2.622
P2 099	162.114	1.402	-12.000	191.388	0.842	-0.271
VL Masoor 133	153.774	-2.012	-1.681	193.053	-0.701	-0.104
Shalimar Masoor-1 (check)	159.224	0.930	2.102	196.612	1.040	-1.383
Overall mean	**162.344**			**197.821**		
SE	0.432	0.116		0.267	0.192	

genotypes and genotype L11 277 showed least deviation from regression. The regression coefficient (b_i) was non-significant for the genotypes except L11 277 and SKUA L 9 and it ranged from-2.01 to 3.94. Thus, these genotypes were average in stability and well adapted to environments.

4.3.1.2 Days to maturity

The genotype L 11 299 and P2 099 were earlier to mature compared to overall mean (Table-4). The days to maturity ranged from 190.669 (L 11 299) to 199.331 (SKUA L 9). Regression coefficient value around unity was observed for the genotypes SKUA L 9, Shalimar Masoor-1, and VL Masoor 507, however deviation from regression was observed non-significant for all the genotypes. The regression coefficient deviating from unity indicates its sensitivity to environmental and stability parameters S^2d_i elucidate the inconsistency or unpredictability of genotypes across all test locations/environments.

4.3.1.3 Plant height (cm)

The stability parameters b_i and S^2d_i along with the mean values for plant height are presented in (Table-5) revealed that the tallest genotype was VL Masoor 507 (44.974 cm) and shortest VL Masoor 129 (29.029 cm), with the mean plant height ($\overline{X}$) of all the cultivars being 36.318 cm. The estimation of mean square deviation from the regression (S^2d_i) was non-significant for all genotypes, making it easy to predict stability of this trait over the environments for the genotypes showing non-significant S^2d_i. The linear regression value (b_i) ranged-0.881 to 2.580 and these values were non-significant (no deviation from unity) for all genotypes. All the genotypes showing non-significant S^2d_i and b_i were average in stability and poorly or well adapted to the environments depending upon their generic background.

Table-5: Stability parameters for plant height (cm) and number of pods plant^{-1} in selected Lentil genotypes evaluated across 6 random environments

Genotypes	Plant height (cm)			No of pods plant^{-1}		
	Mean ($\overline{X}$)	b_i	S^2d_i	Mean ($\overline{X}$)	b_i	S^2d_i
SKUA L 9	44.408	0.873	-11.470	52.903	0.951	-0.231
VL Masoor 514	32.923	2.580	-10.170	50.458	0.953	-6.319
VL Masoor 129	29.029	2.024	4.088	51.373	1.072	-5.366
VL Masoor 126	32.317	-0.881	-7.836	51.621	0.596	-8.056
L11 272	32.801	0.251	-10.419	50.546	1.202	-6.644
L11 279	34.557	0.598	-11.011	50.967	1.277	-5.131
L11 277	43.316	0.553	-11.219	58.083	1.021	-0.207
L11 286	33.034	0.530	-11.385	47.313	0.942	-7.057
L11 299	39.992	0.147	-7.596	57.994	1.355	-2.530
VL Masoor 507	44.97 4	1.065	-11.217	54.639	0.852	-0.125
P2 099	33.451	0.569	-10.564	49.504	1.264	-5.688
VL Masoor 133	31.363	2.340	-9.795	47.098	1.300	-9.829
Shalimar Masoor-1 (Check)	39.979	0.589	-10.994	52.253	0.956	-0.251
Overall mean	**36.318**			**52.203**		
SE	0.697	0.263		0.729	0.729	

4.3.1.4 Number of pods plant^{-1}

The mean values and stability parameters b_i and S^2d_i for number of pods per plant are presented in (Table-5). The genotype L11 277 showed highest mean value (58.083) while VL Masoor 133 showed the lowest mean value (47.098) over six random environments with the mean value ($\overline{X}$) of all the genotypes being 52.203. The estimation of mean square deviation from the regression ($S^2 d_i$) was non-significant for all genotypes indicating stability of this trait for the genotypes across locations would be precise. The linear regression value (b_i) ranged from 0.596 (VL Masoor 126) to 1.300 (VL Masoor 133) and these values were non-significant (no deviation from unity) for all genotypes. All the cultivars showing non-significant S^2d_i and b_i were, by and large average in stability and poorly or well adapted to the environments. However, judging from the mean performance it was observed that the genotypes had high mean value as compared to population mean and thus, were well adapted to all the environments.

4.3.1.5 Pod length (cm)

The pod length of the genotypes ranged from 1.084 cm (P2 099) to 1.430 cm (SKUA L9) across the locations with overall mean of 1.239 cm are presented in (Table-6). The estimation of mean square deviation from the regression (S^2d_i) was non-significant for all genotypes indicating stability of this trait for the genotypes across locations would be precise. The linear regression value (b_i) ranged from 0.605 to 2.046 and these values were non-significant (no deviation from unity) for all genotypes. All the cultivars showing non-significant S^2d_i and b_i were average in stability and poorly or well adapted to the environments. The genotypes SKUA L 9, L11 277, VL Masoor-507 and Shalimar Masoor-1 have above average mean performance and therefore are better adapted to all the environments.

Table-6: Stability parameters for pod length (cm) and number of seeds pod^{-1} in selected Lentil genotypes evaluated across 6 random environments

Genotypes	Pod length (cm)			No. of seeds pod^{-1}		
	Mean ($\overline{X}$)	b_i	S^2d_i	Mean ($\overline{X}$)	b_i	S^2d_i
SKUA L 9	1.430	0.878	-0.007	1.809	0.925	-0.004
VL Masoor 514	1.221	0.830	-0.008	1.742	1.000	-0.003
VL Masoor 129	1.227	0.949	-0.006	1.823	0.835	-0.004
VL Masoor 126	1.171	0.770	-0.007	1.752	0.844	-0.004
L11 272	1.163	0.605	-0.008	1.621	0.800	-0.004
L11 279	1.128	1.314	-0.007	1.471	1.783	-0.002
L11 277	1.373	1.075	-0.008	2.000	0.708	-0.003
L11 286	1.221	1.000	-0.008	1.814	1.367	-0.002
L11 299	1.250	2.001	-0.008	1.565	0.981	-0.004
VL Masoor 507	1.389	0.855	-0.008	1.765	0.869	-0.003
P2 099	1.084	2.046	-0.008	1.922	1.000	-0.003
VL Masoor 133	1.117	0.792	-0.008	1.747	0.900	-0.004
Shalimar Masoor-1 (Check)	1.338	0.887	-.0007	1.708	0.989	-0.003
Overall Mean		**1.239**			**1.741**	
SE	0.008	0.178		0.010	0.266	

4.3.1.6 Number of seeds pod^{-1}

The stability parameters b_i and S^2d_i along with the mean values for seeds pod^{-1} are presented in (Table-6) The mean value for number of seeds pod^{-1} ranged from 1.471 (L11 279) to 2.000 (L11 277) with mean ($\overline{X}$) of all the genotypes being 1.741. The non-linear component (S^2d_i) was non-significant for all the genotypes indicating that the stability for these genotypes would be precise. The linear regression (bi) ranged from 0.708 (L11 277) to 1.783 (L11 279) and was found statistically non-significant for all genotypes. Taking into consideration the linear regression coefficient, it was observed that the b_i values were non-significant (b_i = 1) and thus, the genotypes having non-significant S^2d_i values were, by and large, average in stability. However, judging from the mean performance it was observed that the genotypes SKUA L 9, L11 277, VL Masoor-507 and Shalimar Masoor-1 had high mean value as compared to overall mean and thus, were well adapted to all the environments, whereas, rest all genotypes was having mean value less than population mean and thus, were poorly adapted to all the environments.

4.3.1.7 100 seed weight (g)

The mean values and stability parameters b_i and S^2d_i for 100 seed weight are presented in (Table-7). Mean values to assess the 100 g grain weight revealed a range of 2.423g (VL Maoor 129) to 4.806 g (SKUA L 9), with overall mean of 3.393 g.

The deviation from regression (S^2d_i) was non-significant for all genotypes making it possible to prophesy the stability of almost all the genotypes precisely across the environments. The linear regression (b_i) ranged from-0.111 (Shalimar Masoor-1) to 1.237 (VL Masoor 129) and was found statistically non-significant (no deviation from unity) for most of genotypes. All the cultivars showing non-significant S^2d_i and b_i were average in stability and poorly or well adapted to the environments. However, judging from the mean performance it was observed that

Table-7: Stability parameters for 100-seed weight (g) in selected Lentil genotypes evaluated across 6 random environments

Genotypes	100-seed weight (g)		
	Mean ($\overline{X}$)	bi	S^2d_i
SKUA L 9	4.806	0.873	-0.025
VL Masoor 514	3.478	0.571	-0.025
VL Masoor 129	2.423	1.237	-0.022
VL Masoor 126	2.738	0.845	-0.025
L11 272	2.449	0.710	-0.026
L11 279	2.782	5.690	0.102*
L11 277	3.918	0.247	-0.027
L11 286	3.790	0.164	-0.027
L11 299	3.328	0.751	-0.027
VL Masoor 507	4.653	0.687	-0.027
P2 099	2.553	0.764	-0.019
VL Masoor 133	2.607	0.661	-0.026
Shalimar Masoor-1 (Check)	4.594	-0.111	-0.025
Overall Mean		**3.393**	
SE	0.048	1.251	

the SKUA L 9, L11 277, VL Masoor-507 and Shalimar Masoor-1 had high mean value as compared to overall mean and thus, were well adapted to all the environments, whereas rest all genotypes was having as mean value less than population mean and thus, were poorly adapted to all the environments. The rest of genotypes with non-significant S^2d_i value, the b_i values could safely presumed to be equal to unity and thus, could be assumed to be average in stability.

4.3.1.8 Seed yield plant^{-1}(g)

Estimation of stability parameter for seed yield plant^{-1} are presented in (Table-8). The mean value for seed yield plant^{-1} ranged from 2.189 g (L11 272) to 3.939g (SKUA-L 9) with mean ($\overline{X}$) of all the genotypes being 2.990 g. The non-linear component (S^2di) was non-significant for all the genotypes indicating that the stability of these genotypes would be precise. The linear regression (b_i) ranged from 0.437 (VL Masoor 507) to 1.859 (L11 279) and was found statistically non-significant (no deviation from unity) for all genotypes except. All the cultivars showing non-significant S^2d_i and b_i were average in stability and poorly or well adapted to the environments. However, judging from the mean performance it was observed that the genotypes SKUA-L 9, L11 277 and VL Masoor-507 had high mean value as compared to overall mean and thus, were well adapted to all the environments, whereas, rest all other genotypes was having as mean value less than overall mean and thus, were poorly adapted to all the environments.

4.3.1.9 Seed yield plot^{-1}(g)

Estimation of stability parameter for seed yield plot^{-1} are presented in (Table-8). The mean value for seed yield plant^{-1} ranged from 74.426 g (L11 272) to 133.926g (SKUA L 9) with mean ($\overline{X}$) of all the genotypes being 101.725g. The non-linear component (S^2di) was non-significant for all the genotypes indicating that the stability of these genotypes would be precise. The linear regression (b_i) ranged from 0.437(VL Masoor 507) to 1.860 (L11 279) and was found statistically non-significant (no deviation from unity) for all genotypes

Table-8 : Stability parameters for seed yield plant^{-1} and seed yield plot^{-1} in selected Lentil genotypes evaluated across 6 random environments

Genotypes	Seed yield plant^{-1}			Seed yield plot^{-1}		
	Mean ($\overline{X}$)	b_i	S^2d_i	Mean ($\overline{X}$)	b_i	S^2d_i
SKUA L 9	3.939	0.547	-0.102	133.926	0.548	-1.137
VL Masoor 514	2.344	1.077	-0.093	113.696	1.077*	-1.038
VL Masoor 129	2.839	1.381	-0.096	96.526	1.381	-1.063
VL Masoor 126	2.806	0.553	-0.097	95.404	0.553	-1.078
L11 272	2.189	1.192	-0.094	74.426	1.190	-1.043
L11 279	2.278	1.859	-0.079	77.452	1.860	-0.873
L11 277	3.517	0.732	-0.093	119.578	0.732	-1.037
L11 286	2.967	1.123	0.119	100.878	1.127	1.132
L11 299	2.889	1.016	-0.085	98.226	1.016*	-0.942
VL Masoor 507	3.844	0.437	-0.099	130.696	0.437	-1.097
P2 099	2.411	0.851	-0.075	81.974	0.852	-0.834
VL Masoor 133	2.250	1.725	-0.027	76.500	1.722	-0.295
Shalimar Masoor-1 (check)	3.622	0.507	-0.085	123.148	0.506	-0.943
Overall Mean		**2.990**			**101.725**	
SE	0.085	0.064		0.284	0.467	

except VL Masoor 514 and L11 299. All the cultivars showing non-significant S^2d_i and b_i were average in stability and poorly or well adapted to the environments. However, judging from the mean performance it was observed that the genotypes SKUA-L 9, L11 277 and VL Masoor-507 had high mean value as compared to overall mean and thus, were well adapted to all the environments, whereas, rest all other genotypes was having as mean value less than overall mean and thus, were poorly adapted to all the environments.

4.3.1.10 Protein content (%)

Estimation of stability parameter for protein content are presented in (Table-9). The mean value for protein content ranged from 20.598 per cent (VL Masoor 133) to 24.574 per cent (SKUA L 9) with mean ($\overline{X}$) of all the genotypes being 22.251 per cent.

4.3.1.11 Disease scoring (Wilt Incidence)

The data represented in Table 10 revealed that all the thirteen genotypes across all the location were found to be resistant against wilt (*Fusarium oxysporium*) at pre-flowering, flowering and maturity stages of crop growth.

Table-9: Protein content (%) in selected Lentil genotypes evaluated across 6 random environments

Genotypes	Protein content (%)
SKUA L 9	24.574
VL Masoor 514	20.772
VL Masoor 129	20.602
VL Masoor 126	20.021
L11 272	22.408
L11 279	24.371
L11 277	22.443
L11 286	22.224
L11 299	22.689
VL Masoor 507	24.513
P2 099	20.861
VL Masoor 133	20.598
Shalimar Masoor-1 (Check)	21.395
Overall Mean	**22.251**
SE	0.039

Table10: Wilt incidence (%) of 13 Lentil genotypes across six locations (DARS, Budgam, Kehribal, Chakkissardas, Handal bagh, Pulwama, Nagam) at pre-flowering, flowering and maturity stages

Genotype	Pre-flowering	Flowering	Maturity
SKUA L 9	0	0	0
VL Masoor 507	0	0	0
L11 277	0	0	0
VL Masoor 129	0	0	0
VL Masoor 126	0	0	0
L11 272	0	0	0
L11 279	0	0	0
L11 286	0	0	0
L11 299	0	0	0
VL Masoor 514	0	0	0
P2 099	0	0	0
VL Masoor 133	0	0	0
Shalimar Masoor-1 (Check)	0	0	0

Chapter – 5

DISCUSSION

In the present investigation 13 Lentil genotypes were evaluated through mother trial evaluation system to identify the most appropriate genotypes on the basis of preferences of the farmers and to find the varietal specification to bred in future in consultation with farmers. There were six Mother trials laid out in the farmers field including two Grandmother trials laid at Dryland (*Karewa*) Agriculture Research Station, Budgam; Krishi Vigyan Kendra, Malangpora, Pulwama. The experiment was laid in Randomized Complete Block Design (RCBD) with three replications. Further stability of the genotypes was established by following Eberhert and Russell model. Before laying out the trials Participatory Rural Appraisal (PRA) was conducted. The experimental results on these aspects in the light of available literature are discussed below under following headings:

5.1 Understanding farmers' perception and preferences about Lentil genotypes through Participatory Rural Appraisal (PRA)

Participatory Rural Appraisal (PRA) describes a growing approaches and methods to enable farmers to share, enhance and analyze their knowledge of farming practices and conditions, to plan and to act. PRA has sources in activist participatory research, agro ecosystem analysis field research on farming systems, and rapid rural appraisal (RRA). Besides, Participatory Rural Appraisal (PRA) technique is used to establish benchmark information on biophysical, socioeconomic, institutional and farming constraints, as well as farmers' needs, and researchable problems, Joshi *et al*. (2001). In addition plant Participatory Rural Appraisal (PRA) has been employed as an effective tool to get feedback and information regarding the likes and dislikes of end users (farmers) about various traits of Lentil so as to chalk out the strategy for breeding and evaluating the genotypes at farmers field through Participatory Varietal Selection (PVS) in order to increase the adoption rate of released varieties. Similarly the PRA was

conducted to get feedback from end users (farmers) regarding the preferences and perceptions about Lentil crop by Joshi and Witcombe (1998), Loader and Amartya (1999), Collinson and Feldstein (1994), Joshi *et al*. (2001), Katimgi *et al*. (2011) and Gichangi *et al.* (2012).

The PRA results revealed that in Districts of Anantnag and Budgam, Lentil crop is being grown, widely. Source of seed in the sixteen locations was mainly farmers own seed were as market and institution stands at par. PRA across sixteen locations revealed that Lentil is being widely practiced under inter cropping system, however at location Chakki issardas (Anantnag) a good number of farmers (30.23%) were practicing sole cropping. It was found most of the Lentil fields were rainfed and significantly in vogue, however, 44.74 percent of farmers of Chadoora district Budgam grow Lentil under assured irrigated conditions. The data revealed rainfed Lentil cultivation was done on almost 62.17 per cent in district Anantnag and 63.75 percent in district Budgam (Table-1).

Among major production constraints data revealed that low yielding varieties was found to be a significant in limiting Lentil crop production and diseases rank stood second as production constraints. Overall 16 locations the low yielding varieties is the major production constraint and observed data in this regard ranged from 61.11-78.37 per cent. Under the major production constraints another question posed to farmers was regarding the diseases. For varietal preferences of seed yellow-red coloured seed was preferred over black and grey coloured seed and percentage of yellowish-red coloured seed ranged from 48.57 to 80.49 percent.

Regarding the seed size bold seeds were mostly preferred over small seed size. Farmers almost across all locations like bold seed Lentils and this trait scored highest percentage in Devipora (Anantnag) followed by Kawarigam (Anantnag) with a percentage of 78.95 and 78.05 respectively. Regarding maturity, earliness was given more preference in the identified locations. More than 65 per cent of the farmers preferred earliness because farmers in the identified locations takes 2

to 3 different crops in a year across all sixteen locations. Regarding cooking time, farmers across all locations preferred Lentil varieties that took lesser time to cook and its percentage ranged from 54.05 to 76.32 per cent (Table 1).

5.2 Determine preferential scoring of test genotypes on farmers field through farmer selection criteria

Client-oriented breeding explicitly takes into account the needs of end users (farmers, processors and consumers) in designing a new variety and then tests without delay the new products from the breeding programme with the target clients in the target environments (Witcombe *et al.*, 2005). A major component of client-oriented breeding is participatory varietal selection (PVS) where farmers test varieties on their own fields with their own levels of inputs and management. PVS identifies new varieties that farmers prefer to grow for the traits they consider important and facilitates their adoption and spread resulting in positive and rapid impacts on food security and income (Joshi and Witcombe, 1998; Witcombe *et al.*, 2001).

Farmers preferences are very imperative and modern cultivars are often rejected by farmers because of traits that have not been considered in the breeding process (LARC, 1995). The poor adoption of improved varieties may be due to limited accessibility of the new varieties seeds or poor adaptation of improved varieties to local condition (Joshi and Witcombe, 1996). The use of participatory approaches is not new in agricultural development and over the last few decades it has found its way into formal crop improvement (Ceccarelli *et al.,* 2009). This has been in response to the need to improve the impact of research on the livelihoods of farmers. The reasoning has been that if farmers' priorities, needs and capacities are valued and better understood by researchers, extension agents and other professionals, they will be better equipped to make appropriate and sustainable recommendations (Scoones and Thompson, 1994), which, in turn, will positively influence farmers access to new technologies.

The term “participatory plant breeding” has been used to refer to different forms of interaction between farmers and researchers at different stages of the crop research process. It emerged as a concept during the last two decades with efforts to extend the success of modern crop improvement to areas and groups that had benefited less, e.g. small-scale farmers in agro-ecologically and socio-economically marginal and variable environments (Almekinders and Elings, 2001; Ceccarelli and Grando, 2007; Sumberg and Reece, 2004). The objective of participatory plant breeding is to facilitate quicker and more extensive uptake of new cropping technologies by shifting the locus of plant genetic research and improvement toward the local level through direct stakeholder involvement, e.g. scientists, farmers, extension agents, industry, consumers and others, at different stages of the breeding process (Morris and Bellon, 2004).

Hence in present investigation thirteen genotypes including a check were evaluated in Mother trials through farmer’s preferential ranking at four locations laid out in the farmer’s field. Just one week before harvest, Focal Group Discussions (FGD) were used to evaluate the varieties. At village Handal Bagh (Budgam) highest preferential scoring i.e. lowest rank value was recorded on SKUA-L 9 and L11 277 (1) followed by VL Masoor 507 (3) and Shalimar Masoor-1 (4). The lowest preference was recorded for VL Masoor 514(13). Similarly at village Nagam Budgam (Table-4) maximum scoring was recorded for SKUA L 9 (1) and the minimum for VL Masoor 129 and L11 286 (12). At Wantrag Village SKUA-L 9(1) received maximum number of votes and was followed by VL Masoor 507 (2), L11 286 (3) and Shalimar Masoor-1 (4). The maximum farmer’s votes were recorded for SKUA-L 9(1) followed by VL Masoor 507 (2), P2 099 (3) and so on at village Chakki issardas.

There was significant interaction between varieties and locations as observed from the data of preferential ranking. Most of the variations in ranking between sites was for the lower ranked entries. The reasons came to be known for the preference were related to many traits including better crop stand, pod load,

early maturity, good plant height (45-59 cm) and free from diseases. From preferential scoring and estimation of various parameters like maturity, yield and yield related traits genotypes viz. SKUA-L 9, L11 277, Shalimar Masoor-1 and VL Masoor 507 were found to be promising.

The use of PVS proved to be a useful selection method. Farmer participation creates a feeling of ownership (Weltzein *et al.,* 2003). Variety selection by farmers at the same low input farming conditions addresses also the needs of more marginalized farmers (Dawson *et al.*, 2007). It is a rapid and cost effective way to assess and select potential varieties (Abidin, 2004). Joshi and Witcombe (1996) reported that adoption rates of cultivars would be improved through increased farmers' participation. Poor farmers can adopt new varieties as rapidly as wealthier ones through participatory varietal selection.

5.3 Analyze Genotype × Location (G × L) interaction and Stability Studies by Eberhart and Russell model

Further to the above exercise the test genotypes were evaluated to identify high yielding stable genotypes that would further be tested for their general and specific adaptation depending on their performance, and could also be used in future breeding programmes. The real estimate of a genotype gets biased if G × E interaction is present and this results when a crop is grown in a single environment. The multi environmental testing allows removing this basis. The knowledge about the extent of fluctuations of yield and yield attributes over environments is very important to identify genotypes which are widely adapted. Yield is a quantitatively inherited character and there is considerable interaction between genotypes and environments. Some of the crop varieties are widely adapted, while as others are not. Multi-location testing of genotypes provides an opportunity to the plant breeders to study the adaptability of a genotype to a particular environment and also the stability of the genotype over different environments. The information on genotype x environment interaction is of major importance to the plant breeder in developing an improved stable variety. Main

strategy among small-scale subsistence farmers, particularly in marginal areas, is risk minimization. In these areas, stable yields are the key to the sustainable food supplies.

During the past several decades, one of the most important advances in biometrical genetics has been the investigation, elucidation and understanding of genotype x environment interaction. Even though the importance of genotype-environment interaction was recognized well and these were know to be heritable (Jinks and Mather, 1955). The main efforts made by the researchers were aimed to measure this G x E interaction, which helped to recognize well this interaction. It indicates that genotypes react in different ways if environmental conditions change and is of significance for breeders, official test stations and growers. Estimation of the genotype × environment interaction is an important consideration in plant breeding programs because it otherwise reduces the progress from selection in the target environment (Hill, 1975). Significant G × E interaction results from the change in the magnitude of different environments or changes in relative ranking of the genotypes. Consistent performance of a genotype across different sites and/or years is referred to as stability. For a cultivar to be a commercially successful one, it must perform well across a range of target environments where the cultivar has to be commercially grown. Since the genotype x environment interaction has a masking effect on the phenotype, some breeders have adopted to estimate the magnitude of this interaction so that, the precise estimate of stability could be obtained. In order to minimize this interaction, stratification of environments has also been used effectively. The region for which a breeder is developing improved varieties could often be so sub-divided such that the entire environment in the sub-region is nearly homogenous. However, even with this refinement technique the interaction of genotypes with locations in a sub-region and with environments has been encountered at a location over different years and its magnitude has been quite a large (Allard and Bradshaw, 1964).

There is a general agreement among the breeders that average yield alone may not be the sufficient to describe the performance of a certain genotype, since it does not indicate the relative performance as compared to other genotypes over different environments. G × E interaction is a major concern in plant breeding for two main reasons; first, it reduces progress from selection, and second, it makes cultivar recommendation difficult because it is statistically impossible to interpret the main effects (Kang and Gauch, 1996).

The presence of genotype × environment interactions indicate the statistically non-addictiveness of genotypes and environments, which means that differences between genotypes depend on the environment. Existing genotype × environment interactions may, but must not necessarily, lead to different rank orders of genotypes in different environments. The breeder is not interested in knowledge of the numerical amount of G × E interactions *per se*, but is only interested in the existence (or non-existence) of G × E interactions in so far as they lead to different orderings of genotypes in different environments. This concept of G × E interaction is closely related to the concept of selection in plant breeding. The breeder is interested in rank orders of genotypes in different environments and in changes of these rank orders and whether the best genotype in one environment is also the best in other environments, which means that relative characterizations and comparisons of the genotypes are often important than absolute characterizations and comparisons (Huhn, 1996).

The most desirable property of genotypes for its acceptability for commercial cultivation is their stable performance across locations (environments), which is also pivotal for the breeders to develop or identify such genotypes that are stable across a range of environments. Environments may be locations or years or combinations of both. Eberhart and Russel (1966) preferred to measure the environment as deviation of mean of all the varieties at locations from the overall mean and recommended growing of a variety in number of environments representing a full spectrum of possible environmental condition.

Partitioning of mean squares due to [environment + (genotype × environment)] interaction into three components namely; environments (linear), genotype × environment (linear) and deviation from regression (pooled deviation over all the genotypes). An ideal genotype is defined as the one possessing high mean performance, with regression coefficient around unity ($b_i = 1$) and deviation from regression (S^2d_i) close to zero. The linear regression is regarded as the measure of linear response of a particular genotype to the changing environment. If the regression coefficient (b_i) is greater than unity, the genotype is said to be highly sensitive to environmental fluctuations but adapted to high yielding environments. If the regression coefficient (b_i) is equal to unity, it indicates the average sensitivity to environmental fluctuations and adaptable to all environments. If the regression coefficient (b_i) is less than unity, it indicates less sensitivity to environmental changes and if this is accomplished by a high mean value, then the genotype is said to be better adapted for poor conditions. The non-significant linear (b_i) and non-linear (S^2d_i) estimates indicate average stability of genotypes across different environments, whereas significant b_i and non-significant S^2d_i values indicate stability to specific environments. However the significance of S^2d_i estimate, irrespective of whether the corresponding b_i estimate is significant or non-significant would suggest that the behavior of the genotype is unpredictable. Comstock and Moll (1963) suggested that selection would not be effective due to presence of significant genotype × environment interaction. Therefore, breeders should give emphasis on stable performance of a line over wide range of environments

In the present study stability parameters such as mean ($\overline{X}$), regression coefficient (b_i) and deviation from regression (S^2d_i), as suggested by Eberhart and Russell (1966) were considered to explain and discuss the stability of different genotypes for various characters under consideration.

As per Eberhart and Russell model (1966) analysis of variance revealed the existence of significant differences among the genotypes for all the traits

studied i.e. days to 50% flowering, days to maturity, plant height (cm), number of pods plant^{-1}, pod length (cm), seeds pod^{-1}, seed yield plot^{-1} (g), seed yield plant^{-1} (g), protein content and 100-seed weight (g) indicating the presence of genetic variability in the experimental material under investigation. Mean squares due to environment + (genotype × environment) were significant for all the traits depicted the distinct nature of environment and genotype × environment interaction on phenotypic expression. Similarly total genotype × environment was found significant except the traits of protein content and. Genotype × environment (linear) interaction component showed high significance for all traits indicating location (environment) had a marked influence on the expression among the genotypes and behavior of the genotypes could be predicted over environment more precisely. Mean square due to environment (linear) component was found to be non-significant for 100-seed weight, for all the other characters the component was observed to be highly significant implied that means of genotypes varied considerably at different locations. Result of significant pooled deviation for all the traits suggested that the performance of different genotypes fluctuated significantly from their respective linear path of response to environments. Predominance of linear component of genotype × environment to non-linear component (pooled deviation) suggested that genotype × environment interaction was predominantly the outcome of linear function of genotype × environment and performance can be predicted across the environments with great precision. The considerable response of genotypes has also been reported by Rafi *et al.* (2004), Dar *et al.* (2009) and Mwale *et al.* (2009), Dehghani *et al.* (2008), Mohammadi *et al.* (2011).

`The failure of a genotype to give the same phenotypic performance when tested under different environments is the reflection of the genotype environment interaction. It was observed by Yates and Cochran (1938) that the magnitude of the genotype × environment interaction in the determination of the phenotypes shown by a number of genetically different lines or varieties raised in a range of

different environments could be related to the overall effects of the environments. Also a genotypes showing a constant performance in most of the environments does not respond to improved growing conditions with regard to increase in yield. Therefore, most agronomists, no longer regard this type of stability as desirable, their objective is a variety which could always show the yield expected at a level in productivity of the respective environments as measured by the average yield of all treatments in that environment i.e., a variety that shows no G x E interaction.

The mean yield of a genotype and the slope of its regression line is used to determine the stability of genotypes over the environments by Finlay and Wilkinson (1963). This method was modified by Eberhart and Russel (1966) who added an extra parameter that measures the deviation from linear regression. The choice of a variety depends on its performance at different location in different years and seasons. Comstock and Moll (1963) suggested that selection would not be effective due to presence of significant genotype × environment interaction. Therefore, breeders should give emphasis on stable performance of a line over a wide range of environment.

In the present investigation, estimation of stability parameters for thirteen Lentil genotypes including Shalimar Masoor-1 variety as check were estimated to identify the genotypes most suitable across a range of environments and for suitable environments. For days to 50% flowering SKUA-L 9 and L11 277 were identified late maturing genotypes and the most stable across six test locations while as for days to maturity L11 299 and P2 099 were observed to be early maturing genotypes. Similarly for plant height and number of pods plant^{-1} SKUA-L 9 was recognized as stable genotypes. The genotypes L11 277 and SKUA-L 9 were reported highly adaptable genotypes across the locations for pod length and number of seeds pod^{-1} respectively as per criteria of Eberhart and Russell model (1966) for fulfilling the status of stability. Further the promising genotypes with respect to consistency for yield was SKUA-L 9, Shalimar Masoor-1 and VL Masoor 507 were found to have wide adaption for seed yield.

Knight (1970) criticized grounds the stability based on linear regression coefficient and deviation from linearity on physiological grounds but nevertheless, the biometrical model given by Eberhart and Russel (1966) has been highly successful in predicting genotypic performance over a wide range of environments. Jinks and Mather (1955) observed that above average performance of a genotype is indicative of the fact that the capitalization of additive type of gene action and residual genetic heterozygosity coupled with critical structural variability could confer wider adaptability to the genotypes.

Based on the above discussion, SKUA L 9 and VL Masoor 507 was identified as most stable across all test locations for yield and other triats, emphasize the importance on revalidation of the results by carrying out the experiment on more number of locations for one more year and then to recommend these varieties with high degree of conviction for such agro-ecologies of Kashmir.

Farmers in the low production potential system are not benefiting long after green revolution and Participatory Varietal Selection (PVS) can solve this problem. Less formal methods of Participatory Varietal Selection (PVS) are most cost effective and can be organized by plant breeders, government extension agencies or NGOs. A major challenge will be the reform of policies so that participatory research can be officially incorporated into varietal testing release and extension systems. More varieties need to formally or informally, released on the basis of participatory data to cater for the diversity of niches found in more productive environments. Such policy changes are vital, because the yield grains from varietal replacement in more productive agricultural environments, although likely to be lower in percentage terms than those found in marginal areas, produce higher absolute gains in yield per area.

Chapter – 6

SUMMARY AND CONCLUSION

The present investigation entitled “Participatory varietal selection in Lentil (*Lens culinaris* M.)” was carried out to identify the most appropriate genotypes on the basis of preference of the farmers on the test varieties and determine their tastes and aspiration for the new varieties to be bred in future in consultation with farmers. The study was undertaken during *Rabi* 2013-14 in two districts viz., Anantnag (33-34˚ E latitude 74-75˚ N Longitude) and Budgam (34-36˚ E latitude 74˚ N Longitude). In each district two locations were selected for laying out the Mother trials, besides two Grandmother trials at Dryland (*Karewa*) Agricultural Research Station, Budgam and Krishi Vigyan Kendra, Pulwama in RCBD design with three replication. Each genotype was represented by two rows of 3m length with row to row and plant to plant spacing of 30 and 10 cm respectively. The experimental material consisted of thirteen Lentil genotypes including popular variety (Shalimar Masoor-1) as check genotype. The observations were recorded on days to 50 per cent flowering, days to maturity, plant height(cm), pods plant^{-1}, pod length (cm), number of pods plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1} (g), seed yield plot^{-1}(g) and 100 seed weight(g).

Participatory Rural Appraisal (PRA) conducted before laying out the research trials revealed that Lentil crop is mainly used for dual purposes and mixed-cropping is usually in vogue and Lentil crop is usually grown as rainfed crop. Among major production constraints, low yielding varieties were considered important and farmers saved seed of conventionally grown varieties is the main source of seed to raise the new crop. Further, the farmers would like to demand the variety possessing early maturity, yellow/red coloured and bold seeded varieties with good drought tolerance and less cooking time.

The preferential scoring of test genotypes revealed that most preferred genotype on the basis of lowest cumulative rank was SKUA L 9 with mean preference rank of (1.00) and VL Masoor 507 as second best (2.25) followed by

Shalimar Masoor 1 (4.75). The genotype that received maximum number of negative votes was VL Masoor 514 (10.75). Farmers who grow the trial and the neighbors of those farmers, expressed a consistent large and highly significant preference for SKUA L 9, VL Masoor 507 and Shalimar Masoor-1 compared with the varieties. Also genotypes L11 279, L11 286 and L11 299 were statistically found at par in term of rank summation index and mean preference ranking and significantly different with the genotypes.

Analysis of variance revealed the existence of significant differences among the genotypes for all the traits studied indicating the presence of genetic variability in the experimental material under investigation. Mean squares due to environment + (genotype × environment) were significant for all the traits depicted the distinct nature of environment and genotype × environment interaction on phenotypic expression. Similarly total genotype × environment was found significant except the traits of protein content and. Genotype × environment (linear) interaction component showed high significance for all traits indicating location (environment) had a marked influence on the expression among the genotypes and behavior of the genotypes could be predicted over environment more precisely. Mean square due to environment (linear) component was found to be non-significant for 100-seed weight, for all the other characters the component was observed to be highly significant implied that means of genotypes varied considerably at different locations. Result of significant pooled deviation for all the traits suggested that the performance of different genotypes fluctuated significantly from their respective linear path of response to environments. Predominance of linear component of genotype × environment to non-linear component (pooled deviation) suggested that genotype × environment interaction was predominantly the outcome of linear function of genotype × environment and performance can be predicted across the environments with great precision. On the basis of stability parameters SKUA L 9 and VL Masoor 507 were identified as the most stable genotypes for grain yield across all locations on the basis of high

mean performance and non-significant estimates of b_i and S^2d_i from unit and zero respectively.

CONCLUSION

Based on the findings of the present investigation the following conclusion can be drawn:

i. Participatory rural appraisal (PRA) helped in understanding the farmers' perceptions regarding Lentil genotype cultivation and finally to channelize relevant genotypes available for them in order to get harness maximized benefits from available genetic material, pipeline, released and breeding lines available with research stations.

ii. PRA gave cognizance to breeders to breed for such varieties for Kashmir valley which should possess high grain yield together with wilt resistance, yellow-red colour range and bold seeded Lentil genotypes along with more number of pods plant^{-1} and erect stature.

iii. Farmers were enthusiastic in selecting Lentil genotypes through Participatory varietal selection (PVS). Out of thirteen genotypes three elite genotypes viz. SKUA L 9, VL Masoor 507 and L11 277 got highest preferential score at all four locations and can be further evaluated under baby trails.

iv. The elite genotypes revealed that performance could be predicted across environments because all these genotypes had expressed non-significant deviation from regression (S^2d_i) for the most of traits yield. Some of the genotypes like SKUA L 9, VL Masoor 507 and L11 277 possessed high yielding and performed well across the environments.

v. From both participatory varietal selection and Stability analysis genotypes viz. SKUA L 9 and VL Masoor 507 can be further evaluated in baby trails as these genotypes were stable for most of the traits across environments and got highest preferential score in Participatory Varietal Selection.

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ANNEXURE– I

RESULT OF PRA IN LENTIL

DISTRICT: ----------

LOCATION: ----------

COMPONENT 1: CROP AND VARIETAL PROFILE			
1.	SOURCE OF SEED	FARMERS OWN SAVED	
		INSTITUTION	
		MARKET	
COMPONENT 2: MANAGEMENT PRACTICES-			
1.	FARMING SYSTEM	SOLE CROP	
		MIXED CROP	
		INTERCROP	
2.	IRRIGATION SYSTEM	RAINFED	
		ASSURED IRRIGATION	
COMPONENT 3: MAJOR PRODUCTION CONSTRAINTS			
1.	LOW YIELD		
2,	DISEASES	WILT	
COMPONENT 4: VARIETAL PREFERENCES			
1.	COLOUR OF SEED	YELLOWISH-RED	
		BLACK	
		GREY	
2.	SEED SIZE	BOLD	
		SMALL	
3.	MATURITY	EARLINESS	
		UNIFORM MATURITY	
4.	COOKING TIME	LESS TIME	
		MORE TIME	
COMPONENT 5: ABIOTIC STRESS			
1.	DROUGHT TOLERANCE		
2.	RECOVERY FROM DROUGHT		

Appendix - II

Mean performance of genotypes for maturity, yield and yield related traits in Lentil, across six random environments

Genotypes	Days to 50% flowering					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	152.000	152.333	152.232	154.000	155.000	157.000
VL Masoor 507	152.667	152.666	153.000	156.000	157.000	159.000
L11 277	158.333	154.333	159.333	161.000	163.000	164.000
VL Masoor 129	156.667	157.667	157.333	160.000	162.000	165.000
VL Masoor 126	159.000	157.000	159.334	163.000	164.667	166.000
L11 272	161.000	162.667	160.667	166.000	167.666	169.000
L11 279	160.000	158.333	159.000	161.000	163.000	166.000
L11 286	160.000	161.000	161.000	165.000	166.000	168.333
L11 299	156.000	154.667	156.000	161.000	163.666	165.000
VL Masoor 514	156.333	154.333	157.667	159.667	161.000	163.667
P2 099	157.333	158.000	159.333	163.000	167.000	168.000
VL Masoor 133	161.667	162.667	161.000	166.667	167.333	169.333
Shalimar Masoor-1(check)	156.333	155.666	158.333	160.000	161.000	164.000
CD 5%	**2.348**	**2.977**	**1.569**	**5.139**	**5.695**	**4.982**

E_1=DARS, Budgam E_2=Handal bagh E_3=Pulwama E_4=Nagam E_5=Kehribal E_6=Chakkissardas

Appendix–II Contd…..

Genotypes	Days to maturity					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	193.666	193.000	195.000	196.666	197.666	202.000
VL Masoor 507	194.000	194.000	195.666	196.666	197.000	201.000
L11 277	196.000	196.000	196.000	196.666	197.666	201.000
VL Masoor 129	194.666	195.666	196.666	197.000	198.000	204.666
VL Masoor 126	195.666	195.666	197.000	198.666	199.000	203.666
L11 272	197.000	196.666	198.333	199.666	200.000	204.666
L11 279	195.000	197.000	197.000	198.000	199.000	202.666
L11 286	195.666	195.333	197.666	198.666	199.000	203.666
L11 299	196.666	196.666	198.000	198.666	199.000	202.000
VL Masoor 514	197.000	197.666	198.666	199.666	200.000	202.666
P2 099	196.000	197.000	198.000	199.000	199.666	201.000
VL Masoor 133	195.000	196.000	195.666	197.666	198.666	199.666
Shalimar Masoor-1 (Check)	194.000	195.666	195.000	196.000	197.000	201.666
CD 5%	**0.492**	**1.347**	**1.488**	**0.820**	**0.718**	**0.561**

E_1=DARS Budgam E_2=Handal Bagh E_3=Pulwama E_4=Nagam E_5=Kehribal E_6=Chakkissardas

Appendix –II Contd…

Genotypes	Plant height(cm)					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	47.400	45.066	44.446	46.066	41.066	42.200
VL Masoor 507	48.633	45.633	45.680	46.633	40.633	42.633
L11 277	45.200	44.866	43.226	43.533	41.533	41.533
VL Masoor 129	30.140	34.473	33.806	33.806	20.806	21.140
VL Masoor 126	37.760	31.766	32.760	31.760	30.426	29.426
L11 272	34.300	32.306	32.300	33.300	30.966	33.633
L11 279	42.130	38.136	39.130	40.296	38.130	42.130
L11 286	37.200	34.843	33.533	35.866	33.033	32.866
L11 299	35.200	33.206	32.533	34.200	31.533	31.533
VL Masoor 514	39.700	36.373	34.033	38.200	24.700	24.033
P2 099	35.926	34.166	31.826	34.826	32.130	31.826
VL Masoor 133	37.420	35.426	33.086	35.420	23.740	23.086
Shalimar Masoor-1 (Check)	42.500	39.833	39.873	41.166	39.000	37.500
CD 5%	**10.262**	**9.626**	**10.211**	**8.589**	**6.766**	**8.936**

E_1 = DARS, Budgam E_2=Handal bagh E_3=Pulwama E_4=Nagam E_5=Kehribal E_6=Chakkissardas

Appendix –II Contd…

Genotypes	Number of pods plant^{-1}					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	51.010	50.986	50.420	49.290	49.196	48.516
VL Masoor 507	52.970	53.210	52.036	51.330	50.780	49.510
L11 277	56.393	46.626	54.830	45.026	43.540	42.080
VL Masoor 129	69.836	61.2 30	63.113	60.956	59.256	59.836
VL Masoor 126	63.236	58.420	60.180	59.076	56.230	54.580
L11 272	55.490	53.116	53.896	48.630	46.726	45.416
L11 279	66.516	55.436	59.256	59.786	53.810	53.160
L11 286	55.980	54.663	53.980	49.480	46.420	45.276
L11 299	51.306	47.446	49.786	48.526	43.906	42.906
VL Masoor 514	61.676	54.676	55.506	56.066	52.920	51.900
P2 099	54.080	51.746	54.076	48.000	45.300	43.820
VL Masoor 133	55.456	47.270	48.156	43.220	47.176	41.306
Shalimar Masoor-1 (Check)	50.830	49.996	49.616	49.110	48.466	46.896
CD 5%	**11.389**	**3.537**	**8.638**	**8.473**	**9.260**	**8.165**

E_1=DARS Budgam E_2=Handal Bagh E_3= Pulwama E_4= Nagam E_5=Kehribal E_6=Chakkissardas

Appendix –II Contd…

Genotypes	Pod length (cm)					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	1.490	1.426	1.460	1.450	1.353	1.400
VL Masoor 507	1.430	1.410	1.400	1.426	1.330	1.340
L11 277	1.430	1.410	1.386	1.400	1.310	1.299
VL Masoor 129	1.260	1.246	1.266	1.256	1.156	1.176
VL Masoor 126	1.210	1.180	1.213	1.180	1.140	1.100
L11 272	1.153	1.206	1.190	1.180	1.116	1.130
L11 279	1.290	1.286	1.260	1.290	1.176	1.196
L11 286	1.130	1.203	1.186	1.166	1.046	1.036
L11 299	1.270	1.256	1.226	1.250	1.130	1.190
VL Masoor 514	1.260	1.246	1.250	1.230	1.156	1.183
P2 099	1.160	1.146	1.166	1.126	0.956	0.950
VL Masoor 133	1.160	1.146	1.130	1.126	1.056	1.080
Shalimar Masoor-1 (Check)	1.390	1.390	1.346	1.326	1.256	1.316
CD 5%	**0.275**	**0.276**	**0.290**	**0.285**	**0.212**	**0.236**

E_1=DARS Budgam E_2=Handal bagh E_3=Pulwama E_4=Nagam E_5=Kehribal E_6=Chakkissardas

Appendix –II Contd…

Genotypes	No. of seeds pod^{-1}					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	1.840	1.820	1.820	1.836	1.810	1.730
VL Masoor 507	1.786	1.776	1.766	1.800	1.770	1.690
L11 277	1.996	1.990	1.996	2.020	2.056	1.940
VL Masoor 129	1.850	1.836	1.820	1.830	1.846	1.756
VL Masoor 126	1.780	1.786	1.730	1.750	1.776	1.690
L11 272	1.636	1.666	1.620	1.616	1.626	1.560
L11 279	1.586	1.600	1.580	1.560	1.576	1.486
L11 286	1.526	1.536	1.543	1.436	1.456	1.326
L11 299	1.826	1.796	1.820	1.850	1.892	1.696
VL Masoor 514	1.760	1.800	1.730	1.736	1.756	1.666
P2 099	1.940	1.980	1.910	1.916	1.936	1.846
VL Masoor 133	1.766	1.786	1.750	1.746	1.756	1.676
Shalimar Masoor-1 (Check)	1.636	1.596	1.636	1.596	1.656	1.527
CD 5%	**0.178**	**0.181**	**0.176**	**0.182**	**0.172**	**0.188**

E_1=DARS Budgam E_2=Handal bagh E_3=Pulwama E_4=Nagam E_5=Kehribal E_6=Chakkissardas

Appendix–II Contd…

Genotypes	100-seed weight (g)					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	4.860	4.846	4.806	4.826	4.730	4.766
VL Masoor 507	4.700	4.680	4.646	4.650	4.636	4.606
L11 277	3.933	3.926	3,920	3.890	3.950	3.890
VL Masoor 129	2.510	2.480	2.476	2.340	2.420	2.310
VL Masoor 126	2.760	2.786	2.760	2.690	2.770	2.660
L11 272	2.480	2.480	2.460	2.420	2.466	2.386
L11 279	3.360	3.356	3.340	3.316	3.330	3.266
L11 286	2.620	3.953	2.530	3.506	2.570	2.510
L11 299	3.823	3.783	3.800	3.770	3.793	3.770
VL Masoor 514	3.510	3.480	3.510	3.440	3.520	3.410
P2 099	2.636	2.596	2.570	2.426	2.616	2.470
VL Masoor 133	3.640	2.630	2.620	2.580	2.626	2.546
Shalimar Masoor-1 (Check)	4.533	4.596	4.580	4.590	4.676	4.590
CD 5%	**0.452**	**0.642**	**0.573**	**0.456**	**0.383**	**0.337**

E_1=DARS Budgam E_2=Handal bagh E_3=Pulwama E_4=Nagam E_5=Kehribal E_6=Chakkissardas

Appendix–II Contd…

Genotypes	Seed yield plant^{-1} (g)					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	4.100	3.933	3.966	3.866	4.000	3.766
VL Masoor 507	4.000	3.766	3.866	3.800	3.933	3.700
L11 277	3.700	3.700	3.466	3.366	3.566	3.300
VL Masoor 129	3.200	3.000	2.800	2.666	2,700	2.566
VL Masoor 126	2.933	2.900	2.900	2.800	2.600	2.700
L11 272	2.433	2.333	2.433	2.066	1.966	1.900
L11 279	3.233	2.700	3.100	2.833	2.800	2.666
L11 286	2.766	2.633	2.400	1.966	1.966	1.933
L11 299	3.600	2.200	3.300	2.900	2.900	2.900
VL Masoor 514	3.600	3.400	3.500	3.400	3.166	3.000
P2 099	2.533	2.700	2.400	2.266	2.500	2.066
VL Masoor 133	2.666	2.833	2.200	2.966	1.933	1.900
Shalimar Masoor-1 (Check)	3.700	3.600	3.700	3.600	3.800	3.333
CD 5%	**0.154**	**0.997**	**0.940**	**0.846**	**0.845**	**0.947**

E_1=DARS Budgam E_2=Handal bagh E_3=Pulwama E_4=Nagam E_5=Kehribal E_6=Chakkissardas

Appendix–II Contd…

Genotypes	Seed yield plot^{-1} (g)					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	143.500	137.655	138.810	135.310	140.000	131.810
VL Masoor 507	140.000	131.810	135.310	133.000	137.655	129.500
L11 277	129.500	129.500	121.310	117.810	124.810	115.500
VL Masoor 129	112.000	105.000	98.000	93.310	94.500	89.810
VL Masoor 126	102.655	101.500	101.500	98.000	91.000	94.500
L11 272	85.155	81.655	85.155	72.310	68.810	66.500
L11 279	113.155	94.500	108.500	99.155	98.000	93.310
L11 286	96.810	92.155	84.000	68.810	68.810	67.655
L11 299	126.000	77.000	115.500	101.500	101.500	101.500
VL Masoor 514	126.000	119.000	122.500	119.000	110.810	105.000
P2 099	88.655	94.500	84.000	79.310	87.500	72.310
VL Masoor 133	93.310	99.155	77.000	103.810	67.655	66.500
Shalimar Masoor-1 (Check)	129.500	126.000	129.500	126.000	133.000	116.655
CD 5%	**3.847**	**3.323**	**3.133**	**2.823**	**2.817**	**3.157**

E_1=DARS Budgam, E_2=Handal bagh, E_3=Pulwama, E_4=Nagam, E_5=Kehribal, E_6=Chakkissardas

Appendix–II Contd...

Genotypes	Protein content (%)					
	E_1	E_2	E_3	E_4	E_5	E_6
SKUA L 9	24.641	24.786	23.73	24.756	24.720	24.810
VL Masoor 507	24.526	24.576	24.476	24.516	24.420	24.560
L11 277	22.350	22.486	22.413	22.48	22.416	22.510
VL Masoor 129	20.513	20.630	20.55	20.676	20.580	20.660
VL Masoor 126	19.920	20.060	19.96	20.056	20.040	20.090
L11 272	22.256	22.466	22.41	22.426	22.400	22.490
L11 279	22.260	22.796	22.74	22.786	22.730	22.820
L11 286	24.116	24.563	24.366	24.42	24.310	24.450
L11 299	22.266	22.386	22.316	22.38	22.260	21.733
VL Masoor 514	21.670	21.820	21.736	21.786	21.770	21.850
P2 099	20.840	20.900	20.78	20.866	20.850	20.930
VL Masoor 133	20.526	20.630	20.58	20.64	20.550	20.660
Shalimar Masoor-1 (Check)	21.246	21.456	21.396	21.45	21.340	21.480
CD 5%	**2.992**	**2.947**	**2.951**	**2.926**	**3.384**	**3.470**

E_1=DARS Budgam E_2=Handal bagh E_3=Pulwama E_4=Nagam E_5=Kehribal E_6=Chakkissardas

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. D.K. Verma, Principal Scientist, IGFRI, Srinagar during Viva-Voce examination held on 28.08.2015 have been incorporated in the manuscript entitled **"Participatory varietal selection in Lentil (*Lens culinaris* M.)"** submitted by **Mr. Fayaz Rasool (Regd. No. 2013-A-947-M).**

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