

**Participatory Varietal Selection in Rajmash (*Phaseolus vulgaris* L.) through Mother-Baby trial evaluation system
in Baramulla, Bandipora and Kupwara districts of
Kashmir**

Fayaz Ahmad Shiekh
(2012-413-D)



Division of Genetics and Plant Breeding

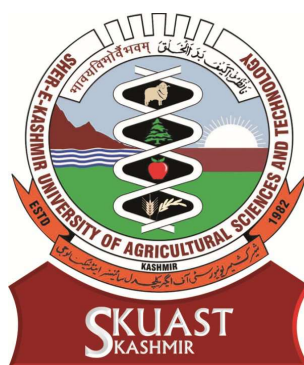
Faculty of Agriculture

**Sher-e-Kashmir University of Agricultural Sciences and
Technology of Kashmir**

2015

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Kashmir**

Fayaz Ahmad Sheikh
(2012-413-D)



Thesis

Submitted to

**The Faculty of Agriculture
Sher-e-Kashmir University of Agricultural Sciences &
Technology of Kashmir**

in partial fulfilment of requirements for award of the Degree of

**Doctor of Philosophy in Agriculture
(Genetics and Plant Breeding)**

2015

GOD SAYS IN QURAN

Say oh Mohammad (saw) to the believers: that,

***"If it be that your fathers, your sons, your brothers,
your mates, or your kindred; the wealth that ye have
gained; the commerce in which ye fear a decline: or the
dwellings in which ye delight - are dearer to you than
Allah, or His Messenger, or the striving in His cause, then
wait until Allah brings about His decision and Allah
guides not the rebellious".***

(Al-Quran, 09, 24)

***Uttaman bin aafan (Ra) narrates that "Prophet
Mohammad (pbuh) said" that***

***"The best among you are those who learn and teach
Quran".***

(mutafiq alai)

DEDICATED

TO

My Beloved

Ummat -e- Muslimah

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

Certificate - I

This is to certify that the thesis entitled “**Participatory Varietal Selection in Rajmash (*Phaseolus vulgaris* L.) through mother-baby trial evaluation system in Baramulla, Bandipora and Kupwara districts of Kashmir**” submitted in partial fulfilment of the requirements for the award of degree of **Doctor of Philosophy 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 Ahmad Shiekh (Registration No.2012-413-D)** under my supervision and guidance. No part of the thesis has been submitted for any degree or diploma.

It is further certified that such help or information received during the course of investigation have been duly acknowledged.

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Title of thesis : **“Participatory Varietal Selection in Rajmash (*Phaseolus vulgaris* L.) through mother-baby trial evaluation system in Baramulla, Bandipora and Kupwara districts of Kashmir”**

ABSTRACT

Present investigation was undertaken during 2012-2014 to generate information on the farmers' perception and preferences about the variety, evaluation of the set of material at the farmers' field along with the farmers' variety as a check through participatory varietal selection. Participatory rural appraisal was conducted in 32 villages from three districts of Kashmir valley namely Baramulla, Bandipora and Kupwara through a broad questionnaires comprising of questions regarding the socio-economic conditions, farming systems, production constraints and varietal preferences of the *rajmash*. The PRA result revealed that the common bean is generally grown as a rainfed and intercropped with maize/ potato/vegetable and merely as sole crop, low yielding varieties and diseases are considered as major challenges in the success of *rajmash* crop, while as red colour with kidney shaped types are highly being preferred.

Based on PRA 54 genotypes belong to pole and bush types were selected. Trials were laid at various locations of three districts summing to a six mother

trials with grand mother trial at the research station. The yield and yield attributing traits of all genotypes was taken on ten competitive plants of both grand mother and mother trial. The participatory varietal selection was carried out at farmers field through farm walk at pod development stage in order to assess the genotype through preferential scoring. The genotypes WB-83, WB-185, WB-195, WB- 966, WB-258 and SR-1 were selected and preferred by the farmers across locations. The genotypes were evaluated for stability analysis and show divergence across locations. The mean squares of all the traits were significant reflecting that the material was generally divergent. The pooled deviation was significant and the variance due to variety $\times$ environment was significant for various traits indicating that the variation in the performance of the genotypes is both unpredictable and predictable. Most of the genotypes were having higher mean than the average, b_i less than unity indicating that the varieties were more specifically adapted to the unfavorable environments than favourable ones. Some of the genotypes having higher mean yield, $b_i > 1$ and S^2_{di} tending to zero were specifically adapted to favourable environments.

Out of the 54 genotypes 6 were selected by paired comparison through baby trial evaluation system. The genotypes were laid with the farmers' variety to make an easy comparison of the important yield and yield attributing traits. The comparison of the test varieties was made on the basis of same, more, less and compared to farmers' variety regarding various traits.

Keyword: Common Bean, PRA, PVS, Stability, Mother Trial, Baby Trial. .

Signature of Student

Dated: _____

Signature of Major Advisor

Dated: _____

Acknowledgement

In the name of "Allah" The most gracious, The most merciful with limitless humility. I seek forgiveness from the Allah, the most beneficent and merciful, besides whom none is worthy for being worshiped, who bestowed me with the courage to go through this crucial juncture.

I take this opportunity to express my deep sense of gratitude and indebtedness for my noble, able and considerate Chairman of my Advisory Committee – Dr. M.N. Khan, Professor and Head Division of Genetics and Plant Breeding SKUAST-Kashmir Shalimar Srinagar, for his uninterrupted guidance, sustained encouragement, unceasing help, constructive criticism with a calm exposure, confidence which led this work to its successful completion and shall remain a lifelong gifted memory for me..

I owe deep debt to thankfulness and heartfelt regards to Dr. P.A. Sofi Assistant Professor Division of Genetics and Plant Breeding FOA, SKUAST-K, Wadura Sopore, for his affectionate and inspiring guidance, careful supervision, wholehearted encouragement and his timely help during the course of investigation.

With the same spirit I would like to express my deep sense of gratitude to members of my Advisory Committee – Dr. Nazir Ahmad Bhat, Associate Professor (Division of Plant Pathology) FOA, SKUAST-K, Wadura Sopore, Dr. Shakeel Ahmad Mir, Professor and Head (Division of Agri-statistics) SKUAST-K, Dr. Wali Mohd Wani Professor, Division of Fruit Science SKUAST-K, for their keen interest, proper guidance and constant encouragement during the entire period of investigation.

I am extremely grateful to Dr. Zahoor Ahmad Dar, Associate Professor Division of Genetics and Plant Breeding SKUAST-K, Dr. Najeeb-ur-Rehman Sofi, Associate Professor Division of Genetics and Plant Breeding SKUAST-K, Dr. Asif Bashir Associate Prof. Division of Genetics and Plant Breeding SKUAST-K for their adroit guidance. They Not only did critical reading of the manuscript, which lead to the elimination of many unavoidable mistakes, but also helped in lending a presentable dimension to this work besides constructive criticism and helpful attitude throughout the course of research work and preparation of this manuscript.

I am deeply indebted to Dr. M. A. Bhat, Prof. and Incharge Deaf Division of Genetics and Plant Breeding, FOA, SKUAST-K Wadura, Sopore, Dr. Gul Zaffar Prof. Division of Genetics and Plant Breeding SKUAST-K, Dr. Gowhar Ali Asst. Prof. Division of Genetics and Plant Breeding SKUAST-K, Shalimar Srinagar.

The timely help and facilities provided by Mr. Irshad Ahmad, Johana and all other office, field and laboratory staff are also heartedly remembered.

I extend my thanks to my colleagues and friends – Iram Saba, Gazala Khan, Asima Gazal, Fayaz Rasool, Mohammad Rafiq, Rayees Lone, Javaid Ahmad, Showkat Ahmad, Wani Sartaj, Reyaz Ahmad, Sajad Ahmad and others have also earned an applause for me for their affection and courage. Their sweet memories will certainly remain an esteemable wealth for years to come.

I do not find words to express sense of gratitude to My beloved Mother Taja Begum, My Father Sona-Ullah Shiekh My brothers Mr. Firdous Ahmad, Mr. Sajad A, Mr. Waseem Ahmad, Mr. Saquib Ahmad, Iftikhar Hussain, Jahangeer Ahmad and sister Ms. Shareefa and Parmeena. I donot forget to mention my cousins and relatives Dr Bilal A. Wani, S. Nazir, Zahoor Wani and Altaf Wani for their support during my studies.

To meet the end of justice and to do fairness to it, it would be bounded duty to put on record a line of utmost gratitude to my beloved Mother Taja Begum, father and sister Ms. Shareefa who as a matter of fact have been real source to put me on the horizons of this success.

At last it will be very difficult to put in few words the support and the favour provided by the library staff, ARIS section and CD room. The Jan Mohammad Sofi and Suhail Ahmad, the support they provided will always remain in my heart.

All those who care for me may not have got a mention, but none shall never be forgotten.

Shaikh Fayaz Ahmad

Place: Shalimar, Srinagar

Date:

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Chapter – 1

INTRODUCTION

Pulses, a variety of plant species belonging to the legume family, include Bambara beans, broad beans, chickpeas, cowpeas, dry beans, dry peas, lentils, lupines and vetches. While varying widely in shape, colour and size, they all share significantly higher protein content-per-gram than most cereal crops and a unique ability to enrich the soil they grow in. Pulses, while fitting easily into the category of “staple crop” for their prevalence as a crop of choice in subsistence farming, are also considered a “specialty crop” in the broader agricultural context. With some important exceptions, the narrow niche they have been assigned has not risen to the level of receiving significant government intervention to increase production and trade, nor have commercial seed producers made substantial investment into their potential. In addition, because pulses remain a comparatively small market, there has been only limited progress in the adoption of industry-wide grading standards and classification of individual pulse species, making trade complicated at times. However, an important milestone occurred recently that will likely have lasting effects on the global market for pulses. In December 2013, the UN General Assembly declared that 2016 will be the **“International Year of Pulses”**. This will likely draw much needed attention to a commodity group which has, despite its many appreciable qualities, proven quite undervalued up until now.

Due to the wide variety of species and cultivars, pulse production is diffused throughout the world, with concentrations on all major continents and can be found in a wide range of latitudes. World production of pulses has slowly and steadily increased since the 1960s at a rate of about 1 percent per year. As indicated earlier, the pace of pulses expansion has not matched that of the other basic food crops. In 2013, total global pulse production stood at 71.7 million tones and 72.2 million tonnes in the year 2014 (predicted) from an area of 72.95 million hectares and average productivity of 0.79 t/hectare (FAO, stat 2014). Global

production of pulses has been marginally increased by 0.2 per cent annually. However, this falls short of projected growth in pulses demand of 2.7 per cent annually and is not adequate to ensure per capita availability of 80g which is a minimum level recommended by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). Analysis of factors responsible for low production and productivity levels indicate a multitude of constraints for the dismal scenario that are biological, geographical, agronomic, institutional and socio-economic in nature. High yielding seeds of pulses have not been made available and many of them have been susceptible to pests, diseases and weather fluctuations. The possibility of improving yield per se through genetic manipulations has been showing encouraging results in recent years.

In 2014, official forecasts point to a record production of 19.8 million tonnes, driven by an increase in plantings, above-average yields and government support measures. India aside, the field of major producers, traditionally relatively narrow, has broadened in recent years with more than 15 countries producing at least 1 million tonnes of pulses in 2014, as compared with just six countries in 1980. In Asia, Myanmar has nearly tripled its pulse production over the last decade, becoming the world's second largest producer after India, with a forecast of 6.3 MMT in 2014. Over 70 percent of its production consists of dry beans with the bulk of total pulse production used for domestic consumption. By contrast, China has shown significant reversal in its position as a world player in the pulses market. As its population has expanded, and per capita GDP has grown, dietary preferences have shifted to include higher value foods. As a result of this, development and due to gradual shrinking of the country's total arable land base, production has more than halved over the last 40 years, decreasing from 8.5 million tonnes in 1961 to the current forecast of 4.2 million tonnes in 2014 (almost equal parts dry beans, peas and broad beans). In the Americas, Canada is a major producer that has made rapid gains in the expansion of pulse area and production over the last two decades. In 1990, Canada produced just 500 000

tonnes while, in 2013, it harvested a record crop of 6 million tonnes (mainly peas and lentils), the bulk of which is destined for exports. Similar to India, large tracts of arable land, good geographic position and favourable climate enable Brazil to have three distinct harvests for beans, with the bulk coming from the central and southern parts of the nation. A bumper crop of 3.4 million tonnes is projected for 2014 following two consecutive years of below average results (FAO, 2014).

For the past 30 years, the single largest producer of pulses has unwaveringly been India, which has consistently produced two to three times more than any other country. India's huge land mass with diverse terrain and climate are such that, pulses are grown during both of the country's main crop seasons (known as "rabi" and "kharif"). India's total output in 2013, put at 18.4 million tonnes, was mainly chickpeas, beans and pigeon peas. India is the largest producer of pulses with a production of 18.5 million tonnes, with the productivity of 0.68 Mt/ha and was cultivated over an area of 26.3 m ha (Anonymous 2015). India is the largest consumer of pulses in the world and also it produces 2-3 times more than any other country in the world (FAO, STAT 2014). At present, it accounts for 33 per cent of the world area and 22 per cent of world production of pulses.

In J&K, pulses are cultivated over an area of about 26.7 thousand hectares with a production of about 14.2 thousand tonnes and productivity of about 530 kg/ha (Anonymous, 2014b). In J&K, *Rajmash* is cultivated over an area of about 2000 hectares with production of about 1600 tonnes and yield of about 8q/ha (Anonymous, 2014b). In Kashmir valley, the yields are disappointingly low at about 5.0-6.0 q/ha. *Rajmash* is usually cultivated at higher elevations in hilly states of North and North East India. In Northern India they are largely cultivated in Chamba, Kinnaur, Rajouri, Baderwah, Kishtwar, Uri, Kupwara, Shopian etc. There is great variation in farmers' preference for the growth habit and seed shape, colour and size. In Ropa Valley of Kinnaur, red capsule types are more preferred, while as small seeded red types are preferred in Salooni, Teesa,

Kishtwar and Bhaderwah and upper tracts of Uttarkashi and Chamoli, yellow types are liked in Spiloo and Moorang areas, small white seeded are preferred in Kalpa and Rogi. In Chauhar valley in HP and Chadar and Dharam valley in Uttarakhand, round mottled types are preferred.

Rajmash (*Phaseolus vulgaris* L.) is the most important pulse crop of the world covering about half of the global pulse acreage. *Phaseolus vulgaris* is a herbaceous annual plant grown worldwide for its edible dry seed or unripe fruit that are both known as “beans”. Its leaf is also occasionally used as a vegetable and the straw as fodder. Its botanical classification, along with other *Phaseolus* species, is a member of the legume family Fabaceae, most of whose members acquire the required nitrogen through an association with *rhizobia*, a species of nitrogen-fixing bacteria. They also leave nitrogen in the soil that enrich soil and become available to the succeeding crop. Besides by opening up of the soil by their deep root system and the huge leaf drop, the crop also enrich the soil humus. Further, due to their plant type and varying maturity duration, the crop is ideally fit in the inter-cropping, relay cropping and multiple cropping. Beans are also important constituents in the diet of a very large number of people, especially in the developing countries and are good sources of protein when taken in pulse form and help to supplement cereal diets, improving their nutritive value. It is self-pollinated crop with a diploid chromosome number of 22. In terms of use category *Rajmash* is classified as dry or pulse type and snap or vegetable types. Snap beans are also called as French beans, String beans, Green beans or Squeaky beans. Despite being called as “Grain of Hope” and “Poor man’s Meat”, this pulse crop has not received the just attention from breeders, farmers’ and policy makers alike due to inherently low yield of pulses, relegation to harsh environments, lack of major technological breakthrough and the lack of encouraging market and price support from the government.

One of the major challenges for improving food security in rural resource poor communities is to develop varieties that are bred for specific environments.

While, varieties are typically developed at a national or international center and incorporate a number of genetically useful traits, it is a major challenge for scientists with limited resources to test the full range of genetic diversity generated by a breeding program under all possible environments. The participatory plant breeding (PPB) process aims to consolidate the farmer's role in setting breeding goals and selecting diverse genetic materials. In so doing it offers skills and opportunities for farmers' to search for new diversity and to select and exchange variable populations that match their local preferences and needs (Sthapit and Jarvis 1999). Also participatory plant breeding (PPB) can add value to traditional landraces that would otherwise be lost from the system (Sthapit *et al.* 2001). Due to inroads made by modern varieties and ruthless import of seeds, on the other hand, the success of participatory plant breeding products may stem from the addition of just a few major genes, corresponding, for example, to pest resistance or plant height (Brown and Young, 1999).

Involving farmers' more actively in plant breeding has been much advocated and described as participatory plant breeding (PPB). The reasons for involving farmers' can vary from empowerment (Sperling *et al.*, 1993) to increasing the efficiency of classical breeding (Witcombe *et al.*, 1996, 2005). Such increases in efficiency are achieved because farmer participation better orients the breeding programme to the needs of the clients. Hence, the purpose of involving farmers' is to improve client orientation and highly client oriented breeding (COB) describes this purpose, while PPB describes an activity (Witcombe *et al.*, 2005). Much research has been done into evaluating varieties with farmers' (e.g., Sperling *et al.*, 1993; Joshi and Witcombe, 1996; Atlin *et al.*, 2001; Witcombe *et al.*, 2005) and this process is now commonly termed participatory varietal, or variety selection (PVS). Less attention has been given to methods of working with farmers' in the segregating generations and there is little evidence in the literature on how this should best be done or, indeed, if it is required at all (Witcombe *et al.*, 2006).

Participatory methods have been used to gather information on important traits, and in facilitating the targeting of breeding programmes for greater impact (Witcombe *et al.*, 2005). Farmers' can provide useful information on plant types, desired traits and insight into trade-offs they are willing to make among traits in designing cultivar types (Sperling *et al.*, 2001). Therefore, if the farmers' priorities, needs and capacities are valued and better understood by researchers, appropriate and sustainable recommendations can be made and thus, increase chances of adoption of new technologies (Scoones and Thompson, 1994).

The recent emergence of the participatory plant breeding movement represents a response to weaknesses of the traditional global approach to plant breeding. The term 'participatory plant breeding' does not refer to a single, well-defined method for plant genetic improvement, rather the term refers to a set of breeding methods characterized by many different potential forms of interaction between farmers' and breeders. What these many forms of interaction have in common is that all are designed to shift the focus of plant genetic improvement research toward the local level by directly involving the end user in the breeding process. Depending on the circumstances, the focus of breeding activity can vary. Prior to the appearance of modern scientific breeding programs all plant breeding was essentially local.

Participatory Plant Breeding has evolved as viable alternative to the conventional plant breeding that lays more emphasis on the involvement of different stakeholder's 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 participatory plant breeding 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’.

While plant breeding programmes across crops have been a driving force in transforming agriculture from subsistence oriented to livelihood and income oriented. A major disparity in impacts in terms of economic upliftment of farmer has been quite obvious, while the varieties have been able to make significant impacts in favourable environments. The impacts have been significantly disproportionate under low input small holder farming systems that are prevalent in crops like *Rajmash*. A major reason for such disparity in impacts has been the unilateral system of varietal development process and obsession of plant breeders with yield. Under small holder farming systems there are traits that are relevant to the farmers’ production constraints and cultural systems which most of the breeding programmes have failed to appreciate.

One of the major changes in varietal development process, is to add relevance to the breeding materials and the finished products, is to incorporate farmers’ socioeconomic and farming system characteristics as well as the production constraints and livelihood opportunities. Such a system warrants a significant and well defined role for farmers in different stages of the breeding programmes. PPB has evolved as a system to address this imperative and involve farmers to breed varieties that are expected to overcome their production constraints, enhance livelihood opportunities as well as fit in their socioeconomic and cultural system. Throughout the world there have been greater debates over the continuation of conventional breeder driven varietal development and dissemination process and there has been equally greater evidence in support of involving farmers as well as other stake holders in the process (Witcombe and associates). PPB is becoming increasingly recognized as a valuable component of technology generation for complex small holder farming systems where poverty is common. Involving farmers is all the more important in view of the fact that there has been a significant disconnect between breeders and farmers perspectives

which is going to bring enumerable risks in that the products may not suit the farmers, may not reach the farmers or appropriate feedback from farmers may not go to the plant breeders.

Rationale of the study

Agriculture in general and *Rajmash* in particular in small holder farming system like in Kashmir suffer from certain inherent bottlenecks such as marginality, fragility, inaccessibility, heterogeneity while enjoying a comparative advantage in niche based cropping system. Therefore any technological intervention including the varietal developmental process has to be fine-tuned in order to enable farmers to harness advantages and overcome the constraints. Plant breeders as outsiders have often failed to appreciate certain important farm and nonfarm characteristics that have a significant bearing on varietal suitability and adoption. It is with this imperative that SKUAST Kashmir initiated participatory varietal selection programmes to add relevance to the process. As a socially responsible process it seeks to empower farmers in decision making and varietal evaluation as well as strengthen the local seed system. The current study is a part of broader research effort in order to identify farmers' production constraints and varietal attributes that will help disseminate appropriate varieties suitable to the farming systems.

Therefore, the study was undertaken to meet out the following objectives :

- Understanding farmers' perceptions and preferences about *Rajmash* varieties through Participatory Rural Appraisal (PRA)
- Screening available genetic resources, landraces, advanced breeding lines as well as pipeline materials based on attributes specified by farmers'.
- Evaluating breeding materials on farmers' fields using farmers' selection indices and criteria through mother and baby trials.

Chapter – 2

REVIEW OF LITERATURE

Plant genotypes adapted to low-input environments and different types of cropping systems are essential for improving agricultural production and farmer livelihoods in developing countries. These low-input cropping systems cultivated by millions of smallholder farmers have unique and diverse environmental conditions that present challenges to effective development of new genotypes. Efforts to develop suitable genotypes include multiple strategies (Gibson *et al.*, 2008). Plant breeding programs have increased the availability of improved genotypes, and there is growing interest in methodologies such as participatory plant breeding (PPB) and participatory variety selection (PVS) that integrate farmer preferences and knowledge (Witcombe *et al.*, 2005; Ceccarelli and Grando, 2007). Farmers' and scientists working together in participatory models can facilitate the research and development of useful approaches that will benefit farmers' and the people who depend on their products. Participatory research encompasses a continuum of models, from researcher led to farmer-led (Biggs, 1989). Depending on the goals of the collaboration and the time constraints of the participants, farmer involvement may range from minimal to very high. A key aspect of participatory research is the flexibility of the model, which allows for projects to develop fluidly in a manner that addresses the needs of all participants.

Various aspects of the current study are reviewed under appropriate heading in light of the available literature below.

Development of Participatory Plant Breeding

Participatory Plant Breeding (PPB) is a form of participatory research that involves scientists and farmers working collaboratively in the breeding process. While the practice of participatory plant breeding is relatively

new, the achievements of scientists and farmers in the field of plant breeding are both extensive and in the case of farmers, date back to prehistoric times. Crops such as barley and wheat were domesticated by humans over 10,000 years ago, and farmers have been selecting seeds and improving varieties in their fields ever since (Cox, 2009).

The rediscovery of Gregor John Mendel's genetic experiments in 1900 sparked the interest of researchers in breeding, and resulted in a tremendous proliferation of new crop varieties, often developed from the traditional land races that had been originally bred by farmers (Kloppenburg, 2004). As researchers began to generate an extensive body of quantitative theory and statistical applications for plant genetic improvement, farmers increasingly have abdicated their role as breeders to those formally trained in the discipline. As a result, the breeding that once occurred mainly in farmers' field now takes place at university and private company research stations. These research stations, often situated on fertile, uniform agricultural land with intensive application of nutrient and water inputs, allow plant breeders to minimize field variation and increase the precision of selection on genetic traits (Atlin *et al.*, 2001). This environment, however, does not allow for the testing of variety performance under stressed conditions such as weed and insect competition, or limited water availability.

Participatory plant breeding has emerged in recent decades with the recognition that farmers and researchers working collaboratively can address this question. Plant breeders in the developing world pioneered this process by moving away from the breeding stations and into the farmers' fields to develop varieties adapted to marginal growing conditions (Pixley *et al.*, 2007). This shift back to farmers' fields has allowed farmers to reengage with the breeding process. Rather than treating farmers as the end users of their product, participatory plant breeders work collaboratively with farmers in various stages of the breeding

process. This includes setting goals, forming breeding populations, implementing effective selection methods and releasing new varieties. Participatory plant breeding around the globe has markedly enhanced adoption of new varieties by prioritizing locally important characteristics, performance in marginal production environments and unique quality traits (Weltzien and Christinck, 2008).

Decentralized, client oriented participatory breeding programs have the goal of increasing adoption of improved varieties for target environments by ensuring farmer criteria for varieties are met (Witcombe *et al.*, 1998). They often include co-learning and sharing of knowledge between scientists and farmers. There are also examples of farmer derived landraces, or indigenous plant breeding, of common bean (Voss, 1992), maize and other crops (Gibson *et al.*, 2008). Participatory plant breeding processes have made considerable advancements in the development of improved varieties for low-input systems but the hurdles are still immense. It is particularly difficult to identify genotypes for mixed cropping systems that meet farmers' needs in the diverse microclimates that exist in Sub-Sahara Africa.

Cereal-legume based intercropping systems are arguably one of the most efficient forms of intercropping due to the nitrogen-fixing properties of legumes, which are complementary to the high nitrogen demand of cereals (Stern, 1993). As such, maize-bean intercropping systems in particular are a ubiquitously grown intercropping system around the world. Over the past few decades a handful of researchers have attempted to breed cultivars for these cropping systems (Francis, 1978ab; Zimmerman *et al.*, 1996; O'Leary and Smith, 2004; Atuahene-Amankwa *et al.*, 2004; Muraya *et al.*, 2006).

The importance of local farmer knowledge and practice in development of sustainable farming systems is readily recognized in agricultural and conservation research (Snapp *et al.*, 2010), and more specifically in the improvement of cultivars through PPB and PVS (Morris and Bellon, 2004). But to our knowledge there is almost no documented information on farmer knowledge regarding the

evaluation or selection of genotypes for an intercropping system. Smallholder farmers have been growing mixed cropping systems for hundreds of years and have likely built up a body of knowledge over generations that could be a potential source of innovation in the improvement of genotypes for bean-maize cropping systems.

In the late 1980's Sperling *et al.* (1993) conducted ground breaking research in Rwanda that improved bean breeding for low-input systems by incorporating expert farmer knowledge into the selection of bean varieties. In concurrent work, Voss (1992) found that bean farmers have particular methods for testing bean varieties in different environments and cropping systems. He found that Rwandan farmers test a bean genotype in a monocrop first and if it performs well in the monocrop, they will test it other environments including low fertility fields and intercrops (Voss, 1992). This is evidence that farmers have unique methods in the selection of genotypes for intercropping systems and this knowledge may inform future breeding strategies.

Modern crop varieties bred in various national and international breeding programmes that 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 socioeconomic profile of farmers', 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.

PPB is an extension of Participatory Varietal Selection (PVS). In PPB,

farmers are actively involved in the breeding process, from setting goals to selecting variable, early-generation material. In PVS, farmers are given a wide range of new cultivars to test for themselves in their own fields. PPB is based on the generalized assumptions that farmers actively participate and the participation is invariably successful. The materials are expected to enjoy greater adoption due to the parents being selected by the farmers evaluated under local systems and evaluated by the farmers'. Thijssen *et al.* (2008) gave the basic components of PPB and are outlined as:

1. *Situational analysis and needs assessment*

- A participatory rural appraisal (understanding community and demands)
- Documentation of local practices (maps, flow charts)
- Documentation of local materials (matrixes, flow charts, four cell analysis)

2. *Search for genetic materials*

- Inventory of local and improved materials (crop diversity and variety maps and matrixes)
- Inventory of pre-released material
- Brainstorming for identification of characteristics and preferred varieties
- Various ranking tools to identify characteristics and materials

3. *On-farm experimentation*

- Cultivation of introduced materials aside with local materials under farmer management
- Farm walks
- Focus group discussions (selection criteria, matrix ranking)

- Post-harvest evaluation

4. *Wider dissemination*

- Community meeting
- Dissemination through kits and fairs
- Monitoring spread and diffusion

Plant breeding programmes, in which farmers' select germplasm for their particular environmental niches, offer the hope of providing well-adapted varieties for the poor (Witcombe *et al.*, 2003; Vernooy, 2003). Participatory varietal selection (PVS) has proved to be highly effective for providing improved varieties which combine agronomic performance and adequate quality traits, in a shorter time and at a lower cost (Joshi and Witcombe, 1996; Tiwari *et al.*, 2009). However, few studies have measured the real effectiveness of decentralized breeding programmes managed by farmers' from early selection generations, compared with centralized conventional breeding. Based on the appraisal of twelve participatory plant breeding (PPB) programmes, Witcombe *et al.* (2006) concluded that collaboration with farmers' at the selection stage globally showed favourable results. He further reported that, compared with formal programmes managed on-station by professional breeders, the PPB programmes may seldom produce genotypes with significantly higher yields, but more often cultivars with an improved balance of traits such as earliness, yield and grain quality can be identified.

2.1 **Participatory Rural Appraisal**

The PRA, when employed in PPB, focuses on the issues relating to the particular target crop. For a breeding programme, well-applied PRA techniques or customer profiling result in better client orientation and make possible efficient goal setting (e.g. Weltzein *et al.*, 1996) or product design (Sumberg and Reece, 2004). Most farmers in developing countries face a multitude of problems which outsiders often fail to appreciate, or even identify (Nabasa *et al.*, 1995). The

unpredictable natural environment most farmers live in and the social, political, economic and personal hardships they face daily are difficult for outsiders to grasp. Outsiders often have severe limitations on the amount of time they can spend in the field or at any particular site. As a result, many studies are conducted and projects implemented without proper consultation with the intended beneficiaries. This often leads to an inappropriate use of resources and in many cases the failure of research efforts to meet their objectives. The ‘conventional’ approach to collecting information from rural environments has been through the use of questionnaire surveys, to generate quantitative data which can then be analyzed statistically. Data from different sites can then be compared. Information can be collected by relatively inexperienced people with the minimum amount of training or knowledge of an area. Information which is outside the scope of the questionnaire often cannot be accommodated and is usually unprocessed and ignored. At best this can affect the perceived relevance of any development project and at worst paint an incorrect picture. In order to address this concern there has, in recent years, been a concerted move towards the development of a more participatory style of development. This type of approach requires the active involvement and participation of the rural people being targeted. This approach has involved the further development of different techniques of information gathering, known collectively as methods of rapid rural appraisal (or RRA), into techniques which involve the active participation of the rural communities (PRA).

Participation of farmers can serve two broad purposes. Firstly, participation can be considered an instrument, i.e. a process by which development initiatives can be more effectively implemented. Participatory methods and tools can be used to incorporate people’s ideas in the development plans, and development or research activities. Secondly, participation can be considered a goal, i.e. empowering the people by helping them to acquire skills, knowledge and experience to take greater responsibility (ownership) for their development.

A successful PRA provides the information needed to specify the characteristics needed in a new variety:

- ***The physical environment.*** This defines where the crop will be grown, the agroecosystem, the common abiotic and biotic stresses and the common management practices including the typical levels of purchased inputs.
- ***The existing varietal diversity.*** The degree of potential fragmentation of the market into a diversity of niche-specific varieties can be understood from the diversity of varieties grown by farmers and the reasons for this diversity. It also identifies locally adapted germplasm that has the greatest potential for use in a breeding programme.
- ***The size of the market.*** The public sector may wish to analyze how poor are the farmers in the target market to see how efficiently public money will alleviate poverty, while the private sector will want to know how many well-off farmers there are (the customer profile) that have the capacity to purchase seed.
- ***The desired traits.*** It identifies the traits needed in a new variety for key traits such as duration and balance between grain and stover. Sometimes these traits may be unexpected, e.g. pericarp colour in rice (Sthapit *et al.*, 1996) and easy threshability in rice (Joshi *et al.*, 2002).

At the end of process, it is expected that a product specification can be made that includes all of the major adaptive, yield and quality traits needed. Hence, perhaps Sumberg and Reece (2004) are unduly pessimistic when they argue that *de facto* PPB programmes do not lead to a new product development orientation. A successful PRA (above) provides everything they argue should be included in the full design specification of a new crop variety. They also point out that while user involvement in product design and development may be valuable, it is not sufficient to guarantee a successful innovation process. For plant breeding this may also be pessimistic because the processes of new product development in

plant breeding are well understood. As Sumberg *et al.* (2003) state, ‘the need is to increase the raw material that farmers can incorporate into their ongoing experimental activities’ and this is exactly what is achieved when new products are tested in PVS trials (Witcombe *et al.*, 2004).

Participatory rural appraisal is an exercise aimed at identification of farmer’s 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, to be tested and avoid the cultivars that will be obviously acceptable (Joshi and Witcombe, 1998). Participation of farmers’ can serve two broad purposes. Firstly, participation can be considered an instrument, i.e. a process by which development initiatives can be more effectively implemented. Participatory methods and tools can be used to incorporate people’s ideas in the development plans and development or research activities. Secondly, participation can be considered a goal, i.e. empowering the people by helping them to acquire skills, knowledge and experience to take greater responsibility (ownership) for their development. The preliminary survey of literature reveals very scanty information about the reported results of PRA in *Rajmash*.

One of the earliest efforts to get an insight into farmers’ assessment of varietal attributes in beans was done by Collinson and Feldstein (1994). They reported that farmer judge bean varieties on the basis of yield, performance under intercropping, performance under adverse conditions, early maturity and grain colour. Frio *et al.* (1994) conducted the regional training courses in gender analysis through participatory rural appraisal and its application to farming systems research (FSR) in south and south East Asia and aimed to assist scientists in national agricultural resource institutes conduct gender-responsive research. The experience of the International Rice Research Institute (IRRI) in the area of gender analysis has been found exploratory and, at best, cuts across regional

differences in culture and environment to improve social conditions of rice growing farming committee.

Joshi and Witcombe (1996) carried out PRA and got the valid information that there was no adoption of improved cultivars in any crop and improved cultivars available on the market did not meet the farmer's needs. The PRA proved to be quick and effective method of identifying and characterizing what the farmers' grow and subsequently showed the importance of PRA as first step in choosing which cultivars should be tested with farmers'. Barik *et al.* (1996) in his study, presented that 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.

David (1999) analyzed at two locations socioeconomic and production constraints of bean based farming systems. In both the locations there were significant differences between households on the basis of wealth. The farm size on an average was smaller in Lugala than Nabongo, with 36% of households compared to 24% of Nabongo households cultivating less than an acre in the first season. In Nabongo, but not in Lugala, farm size was positively associated with wealth. Household labour force involved in bean production did not vary significantly by locality. Over half (58%) of surveyed households in Nabongo, especially the rich, depended on non-household labour for farming. By contrast, in Lugala less than a quarter (21%) used hired or reciprocal labour, a practice not associated with household wealth status. While all households surveyed were fully involved in agricultural production, not all planted crops every season. The status of beans in the two communities contrasts sharply: in Nabongo the crop is considered a principal food and cash crop but holds a lesser status in Lugala

where coffee, bananas and vanilla are the main cash crops and fish is an important source of protein. Beans are intercropped with maize (100% in Nabongo and 64% in Lugala), cassava (25% in Nabongo and 79% in Lugala), bananas (63% and 21%), cotton (30% in Nabongo) and other crops (11 and 14%). In Nabongo, the largest area sown to beans was intercropped with maize (98% of households), matooke (61%) or cassava (36%). In Lugala, the largest areas planted with beans were intercropped with cassava (40% of households) and maize (35%). Significantly, the production constraints identified by farmers' in both locations did not include soil fertility. Farmers' also complained about "worms" and aphids. Although farmers' in both localities recognized yield loss due to diseases (i.e., yellowing leaves, "a lot of rain" 8), in Lugala these constraints received a low ranking, possibly indicating farmers' poor understanding of diseases or their feeling of helplessness regarding the problem.

Nepali *et al.* (1999) carried out a baseline and need identification survey site at Chambas of Tanahun district representing river basins in western Nepal. The participatory rural appraisal technique was used to establish benchmark information on bio-physical, socioeconomic, institutional and farming constraints, farmers' needs and researchable problems and different ethnic groups were found with diverse food preferences were rice and maize followed by millet were found as commonly consumed food staples and women were involved in all the farming activities except ploughing the land. The needs of the farmers were found high yielding and good taste preferences.

Adamo (2001) in Ethiopia used farmers' social networks as 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. Mwaniki in (2002) carried out Participatory Rural Appraisal in Gichera sub-location in Runyenjes in Embu, Kenya, to identify the major constraints faced by bean farmers in this location. The bean production problems were listed by the

community and ranked in order of importance using a pair wise matrix. The constraints were poor or low soil fertility, bean diseases, insect pests and poor road network among others. The PRA was followed up by administration of a semi-structured questionnaire. Based on responses by farmers to the questionnaire, bean diseases were ranked (87.5%) as the most important constraint contributing to low bean yield in the area. This was followed by low yielding bean varieties (62.5%), low soil fertility (52.5%), insect pests (50%), lack of quality seed (17.5%), low market prices (12.5%) and low or high rainfall (10%). It was established that most farmers in the area grow beans in association with maize.

Using Participatory Rural Appraisal in Embu, Kenya, Wangui (2002) surveyed in order to identify the major constraints faced by bean farmers' in this location. The bean production problems were listed by the community and ranked in order of importance using a pair wise matrix. The constraints were poor or low soil fertility, bean diseases, insect pests and poor road network among others. The PRA was followed up by administration of a semi-structured questionnaire. Based on responses by farmers' to the questionnaire, bean diseases were ranked (87.5%) as the most important constraint contributing to low bean yield in the area. This was followed by low yielding bean varieties (62.5%), low soil fertility (52.5%), insect pests (50%), lack of quality seed (17.5%), low market prices (12.5%) and low or high rainfall (10%). In the area most farmers' grow beans in association with maize that was reflected in the study.

Virk *et al.* (2003) conducted PRA to elicit farmer's needs in new varieties through Focal Group Discussion (FGD) and interviews. PRA showed that Knowledge of the constraints of the target area and the traits the farmer require in a variety are important for goal setting in a plant breeding program. The information received through PRA showed that plain seeded varieties were grown by the farmers' and wanted varieties with early maturity, tolerance to major pests and diseases, higher seed yield and good cooking quality.

While conducting PRA in certain bean producing areas in Malawi Chirwa

and Phiri (2005) identified 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. Ferris and Kaganzi (2008) while surveying production and marketing constraints in beans in Ethiopia and outlined that a major constraint mentioned by virtually all contacted farmers was the lack of high quality seed especially for the white varieties for export. Farmers suggested that additional efforts should be made at a commercial and farmer level to introduce projects to increase local availability and access to improved seed types. This should include both the seed types from the public and introduced seed from the private sector. Key areas of intervention suggested by farmers included: Farmer groups should be supported to produce high quality seed to provide inputs into the bean export industry. While conducting PRA in Rwanda and Uganda Mazur *et al.* (2010) established that the production constraints in bean cultivation and concluded from results that the major production constraints identified were unreliable or erratic weather conditions, small land holdings, limited access to seeds, pests and diseases, lack of capital to allow for commercialization of beans, declining soil fertility due to bad eco-management, poor storage facilities, poor drying facilities which result in and poor market transparency.

Using a structured interview Birachi *et al.* (2011) in his study came out with a list of constraints faced by bean growers that limit the production levels including losses during storage and transportation, distance from market, bean prices etc. The farmers' were usually growing low yielding traditional land races accessed through informal local seed systems. Katimigi *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.

In an attempt to understand farmers' perceptions, Gichangi *et al.* (2012) highlighted the need of assessment of farmers' perceptions as an important consideration 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'. Asfaw *et al.* (2012) during his extensive rural survey 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.

Njoki (2013) while surveying in Kiambu County in Kenya using a semi-structured questionnaire, interviews, and focus group discussions, found that farmers' cultivate *Rajmash* during the short and long rain seasons. However, they experience better yields in the short rains due to reduced disease incidence. The majority of the farmers' (71%) intercrop *Rajmash* and this ensures maximum utilization of space. A high percentage (70%) of the farmers' utilize their retained seed for production. The farmers' identified ALS as one of the most important constraints to production. The only preventive measure they undertake to control the disease is weeding. The farmers' reported that they preferred improved varieties that were resistant to ALS.

A study was carried out by Asfaw *et al.* (2013) regarding farmers' variety and seed management practices which reflected that 88% of the area planted with beans was covered by farmer varieties whereas only 12% was planted to improved

varieties. Of all the farmers', 96% were growing one variety (including variety mixtures), 3% were growing two varieties and only 1% had planted three varieties in 2008, which means an average of one variety per farmer and maximum three varieties per farmer. Approximately 90% of survey farmers' grew a pure bean variety while 10% had grown bean variety mixtures in the last five years. The practice of growing variety mixtures did not vary between the seasons but farmers' mostly practiced growing a pure variety under sole cropping and variety mixtures under inter-and relay-cropping systems. Varietal mixtures were grown by a considerable number of farmers' at Amaro while a few farmers' were growing varietal mixtures in Konso and Loma. In variety mixtures, farmers' mix 2 or 3 different grain types, like for example small-red and black or small-red and white. In Boricha farmers' did not grow variety mixtures at all. Boricha farmers' rather practiced planting more than one variety in separate plots as a sole or relay crop. Of the improved varieties adopted by farmers' in the region, 78% grew small-white, 20% small-red and 2% the large-seeded, red-mottled, Andean bean. During the survey season, seven grain types were grown with varying distribution across study sites. Among these, farmers' categorized varieties of small-red, small-white and black into sub-types based on seed shape and growth habit while the remaining ones were not. The varieties varied in their yielding potential, growth cycle and specific traits. Farmers' described small-red as the most preferred variety for local-dish making and for selling at the market. Small-white varieties were preferred for 'kiki' (local stew) and uniform harvest maturity.

Sheikh (2014) carried out Participatory rural appraisal (PRA) prior to laying of trials in different locations of Budgam and Ganderbal. He conducted PRA at sixteen selected sites by predesigned questionnaire and it helped him to know the farmers preferences and perceptions regarding different traits of French bean. The data revealed that farmers preferred genotypes early maturing, higher yield, string-less pods, white coloured seed and freedom from diseases.

Sofi (2015) has reported that women farmers' have significant role in farm

operations as well as cooking, storage and even trade. SKUAST-Kashmir initiated the participatory varietal selection in *Rajmash* in 2012 with the emphasis on revitalizing the niche status of this valuable crop as well as help identify and disseminate better varieties that could meet the farmers' criteria and are able to overcome the production constraints being faced by the farmers'. Structured questionnaires were designed to get an insight into the farmer's constraints, varietal specifications as well as opportunities associated with *Rajmash*. The rural appraisal was done with a greater focus on gender specificity in light of the important role of women in *Rajmash* based farming systems. He reported that female respondents gave some valuable suggestions in case of traits such as culinary and cooking quality, threshability, storage while as men respondents were more interested in yield determinants, marketability and stresses.

Umar (2015) carried out Participatory rural appraisal (PRA) through a predesigned questionnaire prior to laying of trials at different locations of Kulgam and Shopian. The data of PRA at sixteen selected sites revealed that farmers preferred those genotypes having early maturing, higher yield, red coloured seeds, plain coat, tolerance to drought and freedom from diseases.

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. *Rajmash* is being usually grown in marginal environments qualify to be an ideal crop for participatory varietal selection (PVS) approach. The participatory varietal selection 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 CIAT, ICARDA and PABRA (Pan-

African Bean Research Alliance) have undertaken PVS in *Rajmash* especially in African countries where it is an important staple crop.

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, 1996; Joshi *et al.*, 1997, 2005; Witcombe *et al.*, 1999). PVS has been used in many crops and countries. PVS is a very powerful approach for influencing and accelerating the varietal testing and release process (Joshi *et al.*, 2012).

Recent research-extension activities have not generally led to the use of modern varieties and most farmers' still grow landraces and traditional varieties. A key assumption is that adoption of new varieties is poor not because of unwillingness to adopt new technologies, or non-availability of good varieties, but because low-resource farmers' in remote areas have no access to such varieties. This problem has been addressed through, participatory varietal selection (PVS), a farmer participatory approach for identifying improved crop cultivars or varieties (Witcombe *et al.*, 1998; Joshi and Witcombe, 1996).

In traditional crop improvement, farmers' are usually involved only in the final stages of variety testing, generally after varieties have been identified for release. Farmers' often have little or no input regarding the management of these trials or the varieties tested. Farmers' evaluations of the tested genotypes are usually not sought, or if they are, they play little or no role in the decision making process for varietal releases and recommendations (Farrington and Martin, 1988). Possibilities for farmers' participation in selection are as diverse as the nature of

selection itself (Ceccarelli and Grando, 2007; Dawson *et al.*, 2008; Weltzien *et al.*, 1998) and crop varieties have been successfully released through different types of PVS programs (Ceccarelli and Grando, 2007; Joshi *et al.*, 2001). In diverse agro-environments, PVS can provide greater varietal choice, a reliable supply of high quality seed and improved regional marketing capacity (Joshi, 2000).

Sperling and Berkowitz (1994) reported that the farmers' targeted two crucial stages for judging the plants: one at the flowering or pod formation stage and second at maturity. At each stage, farmers' were asked to rate the varieties on a scale of one to five (where one was "poor" and five was "excellent"). As a cross-check, farmers' also picked the "three best" and "three worst" cultivars. Near the end of the evaluation, they could select two or three varieties to take home for testing. The farmers' especially the females were highly enthusiastic about their involvement in selection process.

Participatory Variety Selection (PVS) can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties (Joshi and Witcombe, 1996; Witcombe *et al.*, 1996). Moreover, participatory research increases the job efficiency of the scientists (Bellon, 2001) and farmers' knowledge that enables to be retained effectively from year to year (Grisley and Shamambo, 1993). Research costs can be reduced and adoption rates increased if farmers are allowed to participate in variety testing and selection (Joshi *et al.*, 1995). In addition, production increases when farmers adopt new varieties identified in participatory research (Witcombe, 1999).

Joshi and Witcombe (2002) demonstrated that farmer managed participatory research (FAMPAR) which used formal survey methods, was 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; Joshi *et al.*, 1997).

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 were 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 (Witcombe *et al.*, 2001).

Rosas *et al.* (2003) in his study on the application of participatory methods for the genetic improvement of beans in two regions of Honduras, observed that 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.

Lamin (2005) in his study on participatory varietal selection of *Rajmash* in La Jocuma village of Cuba, reported that, 58 farmers' from La Palma participated, and 50 cultivars (commercial, pre-commercial 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 neighbouring communities. Joshi *et al.* (2005) presented results of participatory crop improvement programs in Nepal and Bangladesh. The cultivars from this highly client-oriented breeding programs were widely disseminated in Nepal through a wide network of NGO and GO partners.

While carrying PVS in French bean in Eastern Ethiopia Asfaw *et al.* (2006), reported that the farmers' selected high yielding lines from among 147 germplasm accessions in on-station trials which were later on evaluated at farmers' fields, in various selection cycles with number of lines progressively decreasing with each selection cycle. The study revealed that farmers' criteria for selection differed at different cycles of selection. In the initial cycle of selection farmers' selected lines based on growth habit, plant height, pod load, pod length, pod clearance from base, early maturity, seed colour, seed size and seed yield but in subsequent cycles, seed colour and seed yield were the deciding criteria. There was significant concordance between farmers' and researchers selection as the varieties selected on farm and on-station namely RAB-585 and AFR-702 out yielded the respective checks at both experiments. They concluded that involving farmers' in selection process in beans can greatly expedite the varietal development that is likely to enhance adoption.

Through participatory variety selection processes that were conducted in Malawi, Mozambique and Tanzania, Chirwa *et al.* (2007), reported that stakeholders (farmers', traders, and consumers) had selected varieties of their choice based on the criteria that they use in different sites. The varieties varied from one site to another, but some were cross cutting: 5 in Malawi, 5 in Mozambique and 10 in southern highlands of Tanzania. The selection criteria were also different across sites, but some were common across sites and countries. These included such selection criteria as: high grain yield, acceptable market

class, resistance to pests and diseases, palatable leaves for green vegetable, grain size, early maturity, cooking ability and taste.

In order to assess the selection efficiency Mbugua *et al.* (2007) compared conventional and farmer-participatory methods in adapted dry bean varieties in 2005 at KARI-Thika (Central Kenya). Sixty-four varieties sourced from ECABREN regional nursery were evaluated for adaptability. The experimental design was 8×8 lattice replicated 3 times. Major diseases that were observed and scored for included BCMV and BCMNV. Twenty farmers' including 9 women from Maragua district in Central Kenya evaluated the varieties at the pod-filling (R8) stage using their pre-identified evaluation criteria. The farmers' selected 20 out of 64 as the best adapted bean types. The 3 varieties selected as the best (and their respective yields) were ECAB 0702 (1067 kg ha⁻¹), ECAB 0063 (1338 kg ha⁻¹) and GLP-2 (1123 kg ha⁻¹), and were selected 18, 16 and 15 times respectively and were selected by an equal number of men and women. GLP-2 (rosecoco) is a currently recommended and widely grown variety, while the other 2 were new genotypes, indicating an opportunity to widen the number of bean varieties that farmers' could grow. Sixteen of the 20 bean lines (80%) selected by farmers' as the best were among the top 31 highest yielding lines after conventional analysis (Analysis of Variance-ANOVA). Nine of the 10 least farmer-preferred varieties (90%) were among the 23 lowest yielding bean lines as determined through ANOVA. It appeared therefore that farmers' could select the best and discard the lowest yielding bean lines at pod-filling stage of bean growth with fairly high degree of precision. Mwale *et al.* (2008) evaluated seven dwarf bean lines at five sites in Malawi farmers' field and observed that the high yielding varieties exhibited stable performance across all locations and seasons.

Ashby in (2009), highlighted that the outcome of PVS is more, as farmers' adopt PVS varieties over wider areas, leading to increased food and income benefits. Another impact is increased research efficiency due to more relevant and desirable research products. While highlighting the impact of PPB and PVS on

various crops in different countries by citing different authors, these are cassava in Brazil and Colombia; pearl millet in Namibia and India; beans in Colombia, Tanzania, Ethiopia and Rwanda; tree species in Burundi; potatoes in Rwanda, Bolivia, Peru and Ecuador; rainfed rice in India; paddy rice in Bangladesh, India and Nepal; maize in Mali, India, Ethiopia, Honduras and Brazil; and barley in Syria, Morocco and Tunisia.

Mulualet *et al.* (2012) used a modification of mother-baby trial system through a single season grandmother-mother baby trial system, 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 unreplicated 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 identifying adapted varieties that are likely to meet their needs.

While conducting PVS in bean Asfaw *et al.* (2012) at Southern Ethiopia at seven sites using researcher-managed on-station and farmer managed on-farm trial system. The selection was carried out at physiological maturity using 1-3 scale (1 = worse, 2= same and 3 = better), as well as at threshing. The selection cycle was started with 38 breeding lines out of which 25 were rejected and only 13 retained out of which four more were rejected in subsequent evaluation. However, the choice of varieties varied between farmers' and across testing sites. The selection was done by breeders, extension agents and farmers' and no single genotype was selected by all which indicates the difference in selection criteria among farmers' and breeders. One line SAB-626 was more often selected, but farmers', extension agents and breeders were unanimous in rejecting two varieties SAB-622 and SAB-650.

Yadavendra and Witcombe (2013) showed that participatory approaches

can be used to rapidly and cost effectively to identify the best existing varieties in a process termed Participatory Varietal Selection (PVS). However, client-oriented breeding (COB) approaches also can produce more readily-adopted varieties as identified by PVS.

While studying farmers' variety and seed management practices in southern Ethiopia, Asfaw *et al.* (2013) described that Farmers' responded, small-red as the most preferred variety for local-dish making and for selling at the market. Small-white varieties were preferred for 'kiki' (local stew) and uniform harvest maturity. Black-seeded varieties were not liked in many places, except Konso, because of its non-attractiveness for eating and the associated low marketability. Carioca-types were preferred for their earliness and thereby the possibility to escape drought stress. However, women did not appreciate carioca beans because of their long cooking time. The red-mottled, large cream and cream-mottled Andean *Rajmash* varieties were liked for their culinary quality: swelling in pot while cooking, good looking dish and flavourful. Farmers' perceived large-seeded Andean and small-white varieties as performing well in sole cropping and on fertile land. Black and small-red type bean varieties were considered adapted to a wide range of production systems.

Joshi *et al.* (2014) discussed three elements that were instrumental in bridging the big gap in mungbean research in Nepal to find a long awaited replacement: (a) partnership with government line agencies to revise variety release procedures; (b) access to new mungbean germplasm from the Asian Vegetable Research and Development Centre; (c) the use of PVS approaches to generate data rapidly for release and to promote the new varieties.

Ravi *et al.* (2014) used to build a communication strategy to help motivate farmers' to use suitable varieties for high yields under sodic conditions. The experience shows that PVS is an effective and reliable approach able to be organized by the researchers, government extension agencies or nongovernmental organizations in regions where the financial need and challenging environments

necessitate locally adapted germplasm. One remaining challenge is the full integration of testing researcher breeding materials and farmer involvement. This will require reforming the testing and introduction policies so that appropriate weightage of participatory results is incorporated into varietal assessment, release and extension systems. More varieties need to be developed with farmer participation to help increase production across the diversity of challenging environments. Such policy changes are quite important because the yield gains from varietal replacement in salt affected environments do contribute to higher absolute gains in yield per unit area (Singh *et al.*, 2014a).

Munawwar *et al.* (2014) carried out the research in which a number of improved pipeline pearl millet varieties including PARC MS-1, PARC MS-2 and Millet 7777 were planted in various agro-ecological zones of Pakistan for 2 years (2004 and 2005). The participatory Mother Trial methodology was for the first time used in Pakistan for varietal evaluation and selection. Six varieties of millet were evaluated along with the local checks. In general, the pipeline varieties developed at the National Agricultural Research Centre had a yield advantage of 22 to 44% over the local checks, and other improved varieties included in the trial. The farmers' were involved in varietal selection process. These varieties were selected by the farmers' on the basis of plant height, maturity, higher yield, resistance to leaf blight, downy mildew and ergot diseases, drought tolerance, and dual (grain cum fodder) nature of the varieties. Based on the evaluation and selection, these varieties are being released for general cultivation in various ecologies.

Sheikh (2014) carried out participatory varietal selection during farm walk when pods were at edible stage. PVS was done through voting, each farmer was given two cards one (white) for preferred and other card (yellow) for non-preferred genotype and finally preferential score was calculated by De-Boef and Thijssen, 2007 and Ceccarelli, 2012) method. From preferential score of individual allocation and pooled locations, genotypes viz. WB-1186, WB-195,

WB-160, WB-1538, WB-249, WB-569, WB-648, WB-1136, WB-941 were most preferred by farmers because most of them were early maturing except WB-941, high yielding, maximum number of pods, string-less, small seeded and less prone to diseases. In all four locations genotype WB-1186 got highest preferential score because of its early maturity, highest number of pods per plant, almost largest pod length and its peculiar character of purple colour of pods.

Umar (2015) carried out Participatory varietal selection during farm walk when pods were at edible stage. PVS was done through voting and preferential score was calculated by De-Boef and Thijssen, 2007; Ceccarelli, 2012) method. From preferential score genotypes WB-184, WB-185, WB-6, WB-420, WB-243, WB-1189, WB-1188, WB-256, WB-22, WB-257, WB-418 Were most preferred by farmers because most of them were early maturing, high yielding, higher number of pods, plain seed coat and less prone to diseases. In all four locations genotype WB-6 and WB-257 were most preferred because of, highest number of pods plant⁻¹, almost largest pod length and less prone to diseases.

The survey of literature reveals that inclusive approach in PVS is important in developing farmer specified varieties. The breeders' theoretical knowledge of science behind varietal development and farmers' knowledge about the traits that merit consideration under local systems are combined to select varieties that are likely to be adopted by farmers'. Participatory varietal selection is designed to meet local farmer's needs without any requirement of being replicable (Humphries *et al.*, 2005). Participatory varietal selection assumes greater significance in view of the fact that the scientists located far from the field have neither the skills nor the capacity to undertake analysis of diversity of opinion that farmers' hold about varieties and their attributes. Breeders have invariably failed to put themselves in shoes of marginal farmers' as attested by rather low adoption rates of improved varieties among this group. Thus involvement of farmers' in this co-breeding at some level is clearly warranted in pursuit of effectiveness and efficiency of plant genetic improvement.

2.3 Genotype $\times$ Location (G $\times$ L) interaction and Stability Studies

Genotype-environment interactions are of major importance to the plant breeder in developing improved varieties. When varieties are compared over a series of environments, the relative rankings usually differ. This causes difficulty in demonstrating the significant superiority of any variety (Eberhart and Russell, 1966). Knowledge of the presence and magnitude of genotype $\times$ environment interactions (GEI) is very important to plant breeders in making decisions regarding the development and release of new cultivars (Chakraborty *et al.*, 1990). Genotype $\times$ environment interaction has been defined as the failure of genotypes to achieve the same relative performance in different environments (Baker, 1988). Moldovan *et al.* (2000) indicated that genotype-environment interactions are of major importance; because they provide information about the effects of different environments on cultivar performance and play a key role for the assessment of performance stability of the breeding materials germplasm. Kang (1998) mentioned that gene expression is subject to modification by the environment; therefore, genotypic expression of the phenotype is environmentally dependant. Stability in performance of a genotype over a wide range of environments is a desirable attribute and depends largely upon magnitude of genotype-environment interaction (Ahmad *et al.*, 1996). Bjornsson (2002) defined the stable genotypes as those having the same reactions with high yield or performance. So, evaluation of performance stability and range of adaptation has become increasingly important in breeding programs (Akcura *et al.*, 2006).

Researchers use the terms adaptation, phenotypic stability and yield stability in different ways (Becker and Léon, 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 behaviour and without its estimation, assessment of a genotype remains incomplete (Westcott, 1987). Several researchers have studied this phenomenon and tried to specify and estimate the stability and adaptability of many wheat characters and their response to changing environments but the information regarding the subject is not consistent due to different genotypes and place of experimentation. Eberhart and Russell (1966) proposed pooling the sum of squares for environments and GEI and subdividing it into a linear effect between environments (with 1d.f.), a linear effect for genotype x environment (with E-2 df). In effect the residual mean squares from the regression model across environments is used as an index of stability, and a stable genotype is one in which the deviation from regression mean squares (S_{di}^2) is small.

Twelve parental lines were evaluated and 32 derived segregating populations of beans from a partial diallel in six environments and found that deviation from regression was more in cases of lines than in case of crosses due to the fact that homogenous lines are more sensitive to environments than heterogeneous populations (Takeda *et al.*, 1991). Significant deviations were recorded in 75% of lines as against only 25% of populations. Duarte and Zimmerman (1995) compared various stability methods in *Rajmash* through degree of correlation between various parameters and concluded that there were significant correlations between various stability parameters indicating that different parameters measure similar aspects of phenotypic stability among cultivars. There were significant correlations between regression coefficient and coefficient of determination indicating that latter is sufficient but not essential to measure predictability.

While studying genotype $\times$ environment interactions, genotype response to environments and stability for seed yield of navy bean genotypes (*Phaseolus vulgaris* L.), sixteen genotypes were grown in a randomised complete block

design with three replications at four locations in Ethiopia (Gebeyehu and Assefa, 2003). Genotype $\times$ environment ($G \times E$) interactions was analysed using linear regression. There was considerable variation in seed yield within and across environments. Genotype $\times$ environment interaction was present, the highest being the linear component. The significance of the linear proportion demonstrated the adequacy of the regression model in describing the stability of the bean genotypes. Two genotypes, G 17450 and PAN 134 with respective regression coefficient values of 1.04 and 1.09, smaller S_{di}^2 values, and a relatively high seed yield could be considered the most widely adapted genotypes. The other test genotypes were sensitive to production-limiting factors, their wider adaptability, stability and general performance to the fluctuating growing conditions within and across sites being lowered.

The diverse *Rajmash* material was evaluated consisting of red-seeded landraces currently in cultivation, landraces maintained ex situ in gene banks and two bred cultivars (Gomez, 2004). Molecular and phenotypic evaluation of the plant material was done in contrasting environments. The landraces yielded less than the bred cultivars at the sites with the poorest environments but similarly to them at the other sites. The bred cultivars had longer leaf area duration during the seed filling period and a longer growth cycle altogether compared with the landraces. One bred cultivar (INTA-Masatepe) and two landraces (V16 and V29) showed good yield stability according to the AMMI analysis. Raffi *et al.* (2004) studied $G \times E$ interaction for number of pods and seeds plant⁻¹ in nine genotypes of dry beans in four environments. There were significant variations due to genotypes (G), environments (E) and $G \times E$ interaction for both the characters, which were also highly correlated between themselves ($r = 0.920^{**}$). On the basis of stability parameters (P_i , b_i , S_{di}^2) genotype PB-S8 was found to be most desirable and stable.

An experiment was conducted to study the stability parameters, viz., regression coefficient (b_i) and mean square deviations (S_{di}^2) from linear

regression, along with per-se performance of 13 varieties of bush type French bean for 9 yield related characters (Pan *et al.*, 2006). Highly significant pooled deviation for green pod yield/plant, number of branches/plant, number of pods/plant and pod weight and highly significant/significant $G \times E$ (linear) Interaction for days to 50% flowering, plant height and pod length indicated the preponderance of non-linear components of $G \times E$ interaction. The linear and non-linear components of $G \times E$ interactions were high and low, respectively, for pod width. The roundish and string less podded line EC 350949 was better performing, stable and suitable for favourable environment for green pod yield (23.74 t/ha) and number of pods/plant (20.181 and suitable for unfavourable environment for number of branches/plant (5.141). EC 398564 was also better performing, stable and suitable for favourable environment for green pod yield (16.32 t/ha), pod length (17.63 cm) pod width (1.20 cm), pod girth (0.86 cm) and pod weight (10.68g). EC 398570 was better performing, stable and suitable for favourable environment for pod girth (0.88 cm) and suitable for unfavourable environment for pod length (19.42 cm) and pod width (1.97 cm). EC 350955 was better performing, stable and suitable for favourable environment for number of branches per plant (5.14) and number of pods/plant (18.10) and suitable for unfavourable environment for pod girth (0.90cm).

Temesgen *et al.* (2008) tested *Rajmash* (*Phaseolus vulgaris* L.) genotypes over locations and years with the objective of identifying high yielding, stable and adaptable varieties for western parts of Ethiopia. Regression and AMMI analysis were computed to identify stable genotypes across multi-environments (location-year combinations). Analysis of variance revealed highly significant difference among environment, genotype and genotype $\times$ environment ($G \times E$) interactions, implying that genotypes suitable for specific conditions can be selected. Evidently, MD-23-4, A-802 and LM-93204324 were found to be stable and adapted to wide environments. Genotypes, VAX-2 and Angar were the top yielders but were sensitive to changed environmental conditions, suggesting that

these genotypes produce higher yield under good management and favourable environmental conditions. Therefore, we recommend MD-23-4, A-802 and LM-93204324 for wide adaptation and VAX-2 and Angar for specific adaptation.

The twelve promising genotypes of *Rajmash* (*Phaseolus vulgaris* L.) were evaluated against a standard check at three locations for stability for various yield attributing traits (Dar *et al.*, 2009). Significant differences were observed among the genotypes, $G \times E$ interaction as well as individual environmental effects revealed the presence of variability for the trait under investigation. Significant variance due to $G \times E$ (linear) against pooled deviation indicating that the yield performance of the genotypes could be predicated with greater precision across environments. Genotype SKUA-R-91 possessed high mean values for seed yield across the environments and its regression co-efficient (bi) approaching unity with least deviation from regression co-efficient (S_{di}^2). This particular genotype can be utilized in hybridization for isolating high yielding and stable segregants. The environmental conditions at E_1 were the best for the expression of seed yield. Periera *et al.* (2009) used six stability models to assess stability in Brazilian genotypes of carioca type *Rajmash* and found that many genotypes were stable through many parametric approaches. The genotypes BRS Estilo and CNFC 9518 for high yield, high adaptability and high stability. The yield, stability and adaptability of cultivar Pérola, widely grown in the country, were lower than of the new elite genotypes obtained by the breeding programs.

The stability of some selected genotypes of *Rajmash* was studied by (Razvi, 2012). The experimental material was evaluated in a Randomized Complete Block Design with three replications at three locations, during kharif 2008 for genetic divergence and other genetic parameters and in four random environments during kharif 2009 for stability. $G \times E$ interaction was also significant, revealing that genotypes did not perform equally across all the three locations. Stability analysis of seventeen *Rajmash* genotypes for seed yield plant⁻¹ across 4 random environments revealed that mean square deviation from

regression (S_{di}^2) was non-significant for SKUA-R-05, SKUA-R-11, SKUA-R-12, SKUA-R-16, SKUA-R-19, SKUA-R-25, SKUA-R-28 and PBG-03 and hence prediction of stability for these genotypes were precise and reliable. The linear regression (b_i) was non-significant for SKUA-R-12 and SKUA-R-28 revealing that these cultivars were average in stability. Comparing their performance with the mean, it was observed that SKUA-R-28 was well adapted to all the environments and SKUA-R-12 was adapted to poor environments.

The stability for grain yield, drought tolerance and charcoal rot resistance in *Rajmash* by using Eberhart and Russell method and the Additive Main Effect and Multiplicative Interaction (AMMI) model plus biplot analysis for measuring grain yield (GY) and charcoal rot resistance (CHRR) stabilities in 98 $F_{8:10}$ recombinant inbred lines (RILs) derived from a cross between bean adapted to the tropics (BAT) 477 (resistant) $\times$ Pinto UI-114 (susceptible) were studied by Olivares *et al.* (2012). Experiments were conducted from 2007 to 2009 under irrigated or terminal drought conditions. Annova detected significant differences ($P \leq 0.05$) in GY and CHRR among environments, genotypes and genotype $\times$ environment interactions (GEI). Most RILs showed good responses to unfavourable environments based on GY (48) and CHRR (40). AMMI annova for both traits showed that all sources of variation in the model accounted for approximately 49% of the total squared sum. For the first principal component (PC1), we found 13 RILs that were stable for GY, and for the second (PC2), we found 9 that were stable for GI. For CHRR, we detected 14 stable RILs (PC1) and eight (PC2). Biplot analysis showed the largest vectors for Díaz Ordaz (irrigated and drought, 2008), where the highest and most variable GYs were detected. The shortest vectors were found in Isla (drought, 2007) and Río Bravo (irrigated and drought, 2008), where the lowest and least variable GY were found. They found differential responses of RILs to locations, years and soil humidity conditions as well as significant GEI based on GY and CHRR. The two methods were

complementary and both gave us information to select stable, high-yield germplasm associated with resistance to charcoal rot disease.

The nine *Rajmash* genotypes for yield stability under different sowing dates and watering regimes in three field experiments conducted in the River Nile State-Sudan during 2003 to 2006 were analysed by (Khalifa *et al.*, 2013). Ten test-environments were thus achieved, representing the combined effect of drought and heat stress. Stability analysis (Eberhart and Russell model) was performed 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, appeared to be the most stable. It was concluded that these genotypes can be used to improve *Rajmash* tolerance to drought and heat stress conditions in the Sudan. Some of the genotypes showed moderate or high stability under drought and/or heat stress. The genotypes Ibarya and S/Hashim/98 were considered stable under drought, whereas, Bellenber-1 was the most stable genotype under heat stress. When considering stressed conditions of both environments, Bellenber-1, S/Hashim/98 and DB 190-74-1, appeared to be the most promising and can be used as a source of tolerance to improve *Rajmash* under drought and heat stress conditions.

Pereira *et al.* (2014), carried out the study to investigate the interaction between *Rajmash* lines and water availability on iron and zinc contents (CFe and CZn, respectively), identify superior lines with stable CFe and CZn, and test for a genetic relationship between CFe and CZn. Six crop trials were performed using a randomized block design with three replications. The trials were performed during the winter sowing period for three different combinations of year and site in Brazil. For each combination, 53 lines were evaluated across two parallel trials; one trial was irrigated according to the crop requirements, and the other trial operated under a water deficit. Interaction was detected between lines and environments, and between lines and water availability for CFe and CZn. However, some lines exhibited high CFe and CZn in both conditions. Lines G

6492 and G 6490 exhibited high mean values, stability, and adaptability for both minerals. Other lines exhibited high CFe (Xamego) or CZn (BambuÍ and Iapar 65).

Asfaw *et al.* (2014) carried out the stability for grain yield and other traits over test environments and estimates of stability of the varieties for yield and other traits using cultivar superiority measure. Evaluating varieties based on mean grain yield and stability parameter identified Hawassa Dume as the best variety that combined high mean yield with best estimate for cultivar superiority measure. The drought adapted varieties Dimitu, Red Wolayta and Omo-95 from the Mesoamerican gene pool and Ibado and AFR 702 from the Andean gene pool were good in producing above-average grain yield but were not identified as stable by stability parameter values. Andean varieties Red Kidney and Ibado, and Mesoamerican varieties Melkadima and Ayenew showed stability for expression of the trait 100 seed weight. Majority of the Mesoamerican varieties such as Dimitu, Zebra, Denkenesh, Nasir, Omo-95, Hawassa Dume, SER-108 and RAB-585 had best cultivar superiority estimates for pod harvest index indicating their stable performance across drought stress and nonstress environments in translocating photosynthetically assimilated carbon from pod wall to the grain. None of the Andean varieties showed the same level stability for pod harvest index as the Mesoamerican varieties but Ibado, Goberasha and Cranskope had relatively lower cultivar superiority estimates for the trait. Varieties Argene, Mex 54 and Chore from Mesoamerican group showed stable performance for pods per plant whereas none from the Andean varieties. The Andean varieties Cranskope (V14) and Brown Speckled (V23) and Mesoamerican variety Mex 142 (V9) were inferior in both mean grain yield and stability performance.

Sheikh (2015) carried out estimation of the stability parameters of different genotypes as per Eberhart and Rusells (1966) model revealing that environments + (genotypes $\times$ environment) mean squares were significant for all traits. Partitioning of these mean squares into different components like,

environments, environments (linear), $G \times E$ (linear) and pooled deviation (non-linear) revealed that mean squares due to environments were random and different. The mean squares due to pooled deviation (non-linear) was non-significant for most of the traits. 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 (pod yield). Some of the genotypes like WB-195, WB-1186, WB-941, WB-1538, WB-360, WB-1139, WB-648 and WB-569 possessed high yielding and performed well across the environments.

Musaana *et al.* (2015) studied the stability of pod yield on fourteen snap bean genotypes introduced or locally bred in Uganda. The study was carried out in three seasons using six agroecological zones. All the six non-commercial genotypes had been gene pyramided for rust, Angular leaf spot and common bacterial blight making them tolerant to the diseases. J12 had the highest yields and the commercial variety Paulista had the lowest. Values of bi coefficient indicated that varieties had the highest positive influence on pod yields while location and season had higher negative influence than rust. Variety J 12 and SB001 had the most stable and heavy pod yields. Population dynamics showed that Paulista and Angela had the most unstable plus lowest yields.

Umar (2015) carried out Estimation of the stability of different genotypes as per Eberhart and Rusells model (1966) revealing that environments + (genotypes $\times$ environment) mean squares were significant for all traits viz. days to 50 per cent flowering, days to maturity, plant height, pods plant⁻¹, number of seeds pod⁻¹, seed yield plot⁻¹, Pod length and 100 seed weight. Partitioning of these mean squares into different components revealed that mean squares due to environments were random and different. The mean square due to pooled deviation (non-linear) was non-significant for most of the traits. The elite genotypes revealed that performance could be predicted across environments because all these genotypes had expressed non-significant deviation from

regression (S_{di}^2) for the most of traits. Some of the genotypes like WB-923, WB-22 and WB-83 possessed high yielding and performed well across the environments.

Chapter – 3

MATERIALS AND METHODS

The present study on “Participatory Varietal Selection in *Rajmash* (*Phaseolus vulgaris* L.) through mother-baby trial evaluation system in Baramulla, Bandipora and Kupwara districts of Kashmir” was undertaken during 2012-2014 in three districts of Kashmir valley namely Baramulla, Bandipora and Kupwara which are potential areas for *rajmash* cultivation. The experimental set up is presented below under appropriate headings:

3.1 Selection of study area

In the present study three districts namely Baramulla, Bandipora and Kupwara were selected. In each district two locations (villages) were selected for undertaking the study. These villages were namely, Hajibal (E₁) and Rohama (E₂) in District Baramulla, Langate (E₃) and Warnow (E₄) in District Kupwara, Sumlar (E₅) and Malangam (E₆) in district Bandipora. The selection of sites was done in consultation with KVK's of respective districts and line (agriculture) departments. All the three districts were selected on the basis of their strategic importance. The brief agriculture profile of the districts is given in annexure II.

3.2 Participatory rural appraisal

In order to get an insight into the production constraints and livelihood opportunities of *rajmash* in district Baramulla, Bandipora and Kupwara, participatory rural appraisal was done in the study areas. A questionnaire was drafted in light of available literature and ground information, that aimed at creating a baseline information about the socio-economic status, production systems, management systems, varietal preferences, constraints and opportunities of *rajmash* growing farmers' of the areas of study.

Household surveys and group discussions were held and varietal number of respondents in each location were contacted and information gathered for

questions in the questionnaire. The probing technique was used to derive as much information as possible in order to arrive at a much clear understanding of farmers' perspectives, constraints and their willingness to participate in the process of varietal evaluation and genetic resource conservation through large scale use. The questionnaire used for PRA is presented in Appendix-I. The PRA questionnaire was structured in light of the suggestions made by Professor John Witcombe (per's communication) and different parameters were grouped under appropriate heading to get an insight in to the socioeconomic attributes, farming system attributes, production constraints, varietal attributes and other relevant information. 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.

3.3 Laying of Grand-Mother trials

Grand mother trial is a modified form of mother trial laid on the research station under researcher management to allow optimal trait expression. The trials are laid in replicated design to provide for computation of various components of variation. In the present study 54 lines of *Rajmash* (both pole and bush type) were selected out of the germplasm screening on the basis of yield, maturity and disease reaction. The material represented different market classes of *Rajmash* in order to provide for choice of farmers' in light of their preferences and local market value. The material was grown in a replicated trial with three replications in Randomized Complete Block Design (RCBD) using local varieties provided by farmers' as check. Each genotype was represented by 2metre bed with spacing six rows with a plot size of 2 m $\times$ 2.5 m. Both pole and bush type of *Rajmash* varieties were represented separately at the research station. Data was recorded from 10 competitive plants from each replication for the following morphological, maturity and yield traits:

- i) Days to 50% flowering
- ii) Days to maturity
- iii) Plant height (cm)
- iv) No. of pods/plant
- v) Pod length (cm)
- vi) Pod yield/plant
- vii) Seeds/pod
- viii) 100-seed weight (g)
- ix) Seed yield/plot (g)

3.4 Layout of Mother Trials

The mother trials are used to compare all the entries together in a farmer's field. They are researcher designed but farmer-managed trial at their own field. The mother trial should be usually selected at a central place of the desired location. The quantitative data related to the various traits is being recorded by the researcher himself. Each trial is a single replicate as it has only one plot of each variety. However, the trials are replicated across villages and across farmers' within each village. They not only serve as demonstration plots or focal points for discussions, but provide quantitative, analyzable data on yield and other traits. In baby trials, farmers' compare a single variety (or sometimes two varieties) with the variety they have grown in the past. By giving different varieties to different farmers' all of the promising new varieties from the mother trials can be tested in the baby trials.

Mother trials consist 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 54 breeding lines out of the germplasm collection in gene bank that represented diverse market

class and performed consistently better in station trials were evaluated at six locations namely village Hajibal (E₁) and Rohama (E₂) in District Baramulla, village Langate (E₃) and Warnow (E₄) in District Kupwara, village Sumlar (E₅) and Malangam (E₆) in district Bandipora. The experiment was laid in a replicated design with three replications in RCBD for each genotype represented by 2 metre bed with six rows spaced by 50 cm between plots to allow for farm walk. The farmers' own variety was used as check. At each individual location the trials were designed by scientists but exclusively managed by farmers' to provide for real situation assessment of performances of different genotypes.

Four mother trials of bush type and farmer's variety as check were planted at four different locations. The trials were laid at Longate Kupwara, Rohama Tangmarg, Malangam Bandipora and Regional Research Station Wadura Sopore. The total number of genotypes selected from the bush type were equal to 23. Each genotype is represented by a 2 m bed with six rows. The close spacing was used at all locations including research station trial in order to bring homogeneity to plant responses to spacing, as an attempt to replicate farmers conditions at research station. The genotypes used in the present study are given in the table below.

Table-1: Bush type of genotypes

WB-22	WB-490
WB-147	WB-1031
WB-195	WB-569
WB-216	WB-330
WB-209	Shalimar Rajmash-1
WB-223	WB-479
WB-249	WB-54
WB-191	WB-489
WB-192	WB-487
WB-634	WB-852
WB-462	WB-873
WB-885	

The genotypes that were selected for these villages was done on the basis of participatory rural appraisal, topography and cropping pattern of these villages.

Four mother trials of pole type and farmer's variety as check were planted at four different locations. The trials were laid at Warnov Kupwara, Hajibal Tangmarg, Sumlar Bandipora and Regional Research Station, Wadura, Sopore. The total number of genotypes selected from the pole type were equal to 31. Each genotype is represented by a 2 m bed with six rows. The genotypes of pole type for the selected villages are shown below.

The genotypes selected for these villages were done on the basis of participatory rural appraisal, topography and cropping pattern of these villages.

Table 2 : Pole type of genotypes

WB-38	WB-243	WB-443
WB-143	WB-258-1	WB-409
WB-83	WB-206	WB-411
WB-184	WB-261	WB-1011
WB-158	WB-358	WB-1012
WB-258	WB-128	WB-370
WB-230	WB-224	WB-400
WB-255	WB-240	WB-450
WB-257	WB-1137	WB-330
WB-222	WB-461	WB-1115
		WB-8

3.5 Farm walk and preference score index

At the time of full pod development, 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 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); Ceccarelli (2012):

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

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

3.6 Data collection

The data generated from grand mother and mother trial were collected as:

3.6.1 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 *Rajmash*. The characters included for the study were:-

3.6.1.1 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.

3.6.1.2 Days taken to maturity

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

3.6.1.3 Plant height (cm)

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

3.6.1.4 Number 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 plant⁻¹.

3.6.1.5 Pod length (cm)

Pod length was measured from pedicel up to the tip of pod of the ten competitive plants in each experimental block and average was taken as length of pod.

3.6.1.6 Pod yield plant⁻¹ (g)

Pod yield was recorded from all the ten tagged plants by adding up weight of pods obtained from different pickings and averaged.

3.6.1.7 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.

3.6.1.8 100 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 grams.

3.6.1.9 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 Statistical analysis

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

3.7.1 Participatory Rural Appraisal (PRA)

The results of PRA were analyzed by using t-test to assess the homogeneity of data recorded. The calculated value of t test was tested against tabulated value of t test at 30 degrees of freedom.

3.7.2 Grand mother and mother trial

The observations were recorded for morphological, maturity and yield traits and the data was analyzed by using Windostat for construction of ANOVA and stability using Eberhart and Russell model (1966). The t-test was done manually by using the following formula.

$$t\text{-test} = \frac{X1 - X2}{\sqrt{(S2(1/n1 + 1/n2))}}$$

Where:

S2	=	$\sqrt{SS1 + SS2 / n1 + n2 - 2}$
X1	=	average mean of X1.
X2	=	average mean of X2.
SS1	=	Mean deviation due to X1
SS2	=	Mean deviation due to X2.
N1 & N2	=	number of villages in X1 and X2 respectively.

3.7.3 Statistical analysis of Baby trial data

The qualitative data generated through participatory rural appraisal (PRA) was analyzed by using t-test. The analysis of baby trials was simply carried out, by means of changing the data into percentages individually of the parameter

same, more and less and calculating the general mean of the percentages individually. The standard deviation was also calculated from the data for data interpretation.

3.8 Stability analysis

3.8.1 Analysis of variance for stability

Linear model of Eberhart and Russell (1966) was followed for analyzing the stability of the ten genotypes across three locations each for pole and bush type of *rajmash* varieties. The parameters are defined by the following model:

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

Where,

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

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

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

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

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

Where,

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)	$\left[\frac{\sum_i \sum_j Y^2_{ij.}}{g} - \frac{\sum_i Y^2_{i..}}{n} \right]$
Environment	(n-1)	$\left[\frac{\sum_j Y^2_{.j.}}{g} - \frac{Y^2_{...}}{gn} \right]$
Genotype × Environment	(g-1) (n-1)	$\left[\sum_i \sum_j jY^2_{ij.} - \frac{\sum_i iY^2_{i..}}{n} - \frac{\sum_j jY^2_{.j.}}{g} \right] + \left[\frac{Y^2_{...}}{gn} \right]$
Environment (linear)	1	$\frac{1}{g} \left[\frac{(\sum_i iY_{i..} \cdot \sum_j jI_{j.})^2}{\sum_j jI^2_{j.}} \right]$
Genotype × Environment (linear)	(g-1)	$\left[\frac{\sum_i (\sum_j Y_{ij.} I_{j.})^2}{\sum_j jI^2_{j.}} \right] - \text{Env. (linear) S.S.}$
Pooled deviation	g(n-2)	$\sum_i \sum_j = \sum_i \left[\sum_j Y^2_{ij.} - \frac{Y^2_{i..}}{n} \right] - \frac{(\sum_j Y_{ij.})^2}{(\sum_j I_{j.}^2)}$
Genotype 1	(n-2)	$\left[\sum_j Y^2_{1j.} - \frac{Y^2_{1..}}{n} \right] - \frac{(\sum_j Y_{1j.} \cdot \sum_j I_{j.})^2}{\sum_j I^2_{j.}}$
Genotype g	(n-2)	$\left[\sum_j Y^2_{gj.} - \frac{Y^2_{g..}}{n} \right] - \frac{(\sum_j Y_{gj.} \cdot \sum_j I_{j.})^2}{\sum_j I^2_{j.}}$
Pooled error	n(r-1)(g-1)	Pooled replication S.S x genotypes S.S over environments=Me
Total	(gn-1)	$\left[\sum_i \sum_j Y^2_{ij.} - \frac{Y^2_{...}}{gn} \right]$

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
e = pooled σ^2_e/r

3.8.2 Estimation of stability parameters

$$\text{Regression coefficient (b}_i\text{)} = \frac{\sum_i Y_{ij} I_j}{\sum_j I_j^2}$$

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 (X) of that genotype at each location.

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

Mean squares deviation (S_{di}^2) from linear regression

$$= \frac{\sum_j S_{ij}^2}{n - 2} - \frac{S_e^2}{r}$$

Where,

$$\sum_j S_{ij}^2 = \left[\sum_j Y_{ij}^2 - \frac{Y_{...}^2}{n} \right] - \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

S_e^2 = the estimate of pooled error.

3.8.3 Test of significance

i) Among the variety means :

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

$$F = MS_1 / MS_3$$

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

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

$$F = MS_2 / MS_3$$

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

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

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

For the deviation from regression of each genotype

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

The deviation of b_i values from unity was tested as :

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

Where,

$$\text{S.E. (b}_i\text{)} = \left[\sum_j S_{ij}^2 / n - 2 \sum_j I_j^2 \right]^{\frac{1}{2}}$$

n = number of environments

3.9 Layout of baby trials

The trial nomenclature – mother and baby – followed that of Snapp (1999). Each mother trial was a single, randomized replicate of all of the test entries and controls grown in a farmer's field. The trial was replicated across farmers' fields. The baby trials were single-replicate, single-test-entry trials with farmers' as replicates. Farmers' grew the test entry alongside a check variety in paired plots in the same field, both under the farmer's usual management conditions. There were fewer mother trials because they required more resource for supervision. The methods for participatory evaluation followed those described in Joshi and Witcombe (1996).

The selection of genotypes from the mother trial, were evaluated through baby trials. Out of the total 54 genotypes of both pole and bush type, only six (6) were selected for baby trial evaluation. The baby trials were laid in three districts namely Baramulla, Kupwara and Bandipora of Kashmir valley. The baby trials

were laid both in the area/villages where the mother trials were laid and other villages also. In total there were twenty baby trials across three districts of north Kashmir. The baby trials were not laid at the research stations but exclusively at the farmers' field. In baby trial the area under a particular variety is more as compared to that of the mother trial. Generally one variety is evaluated in baby trial against the farmers' check. We can have two or more varieties to be checked in the baby trial system against the farmers' check. The variety given to a farmer is considered as a treatment with the farmers' as different replicates.

The evaluation of the genotypes in case of baby trials is simply carried out on the basis of same, more or less against the established farmers' check. The comparison of the varieties with the local check and between the varieties was carried out on the basis of farm walk and focussed group discussions (FGD).

Chapter – 4

EXPERIMENTAL FINDINGS

The present investigation entitled “Participatory Varietal Selection in *Rajmash* (*Phaseolus vulgaris* L.) through mother-baby trial evaluation system in Baramulla, Bandipora and Kupwara districts of Kashmir”, was carried out for evaluation of released varieties, pre-released materials, advanced breeding lines, landraces or germplasm accessions on farmers’ fields under his management practices. Fifty four genotypes of *rajmash* both pole and bush types were evaluated to identify genotypes suitable for specific niche areas. Besides the genotypes were assessed for the stability in their performance to characterize the nature of genotype $\times$ location interaction for various yield and yield related traits at different environments. The genotypes were evaluated in a Randomized Complete Block Design (RCBD) with three replications across four random environments each for both pole and bush type separately. So in total 54 genotypes of both pole and bush types were laid at four different locations. The results of the study for mother trials are presented below under appropriate headings :

- 4.1 Understanding farmers’ perception
 - 4.1.1 Background information
 - 4.1.2 Understanding farmers production constraints
 - 4.1.3 Understanding farmers’ varietal preferences
- 4.2 Preference score
- 4.3 Analysis of variance
- 4.4 Stability parameters

4.1 Understanding farmers' perception

After conducting participatory rural appraisal, the perception of farmers' regarding different traits of *rajmash* was worked out. The t-test analysis (Table-3) revealed that the farmers' preference was highly significant for most of the traits. Farmers' perception for *rajmash* is discussed under following headings:

4.1.1 Back ground information

There were 13 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.

4.1.2 Understanding farmers' production constraints

4.1.2.1 Ranking of *Rajmash* among kharif pulses

Across all locations the response of farmers' who were growing *rajmash* as main season kharif crop among all pulses was 82.09%. The *rajmash* (*Phaseolus vulgaris* L.) ranked first in cultivation when compared with other pulse crops. However at various locations (Village Potosa in District Baramulla and Village Quolmuqam in District Bandipora and Village Langate in District Kupwara) the cowpea (warmuth) was cultivated to a considerable extent with a percentage response of farmers' who grow cowpea besides the main season *rajmash*, was equal to 30, 30 and 23.3% respectively. Village Warnov in District Kupwara, Village Malangam-B in District Bandipora and Village Waniloo in District Baramulla showed highest percentage response of farmers' preference towards *rajmash* in their respective districts (the percentage is 92.5, 92 and 87.5 respectively). The t-test comes out to be significant which is equal to 9.9 and is higher than the tabulated value of 1.697 at 30 degrees of freedom (Table 3.1), indicating that *rajmash* is the main season Kharif crop among all pulse crops.

4.1.2.2 Farming practices (mixed crop versus sole crop+ inter-crop)

Across all locations the average number of farmers' that were growing

rajmash as a mixed crop was 79.34%. *Rajmash* is being widely grown as mixed crop with maize, potato and vegetable. However at various locations, considerable number of farmers' were also growing *rajmash* as a sole crop. Village Sewar in District Kupwara, Village Shutloor in District Bandipora and Village Qudar and Quolmuqan in District Bandipora is having 90, 86.6, 90 and 90 percent of farmers' who are growing *rajmash* as a mixed crop. However Village Butgund in District Kupwara, Village Waniloo in District Baramulla and Village Arin in District Bandipora substantial percentage of farmers' grow *rajmash* as a sole crop (to the tune of 16, 50 and 28 respectively). The comparison was significant between the mixed crop verses sole crop as the calculated value of t-test comes out to be 6.9 (t tabulated= 1.697 at 30 d.f.).

4.1.2.3 Irrigation system (Rainfed versus assured)

Across all locations the substantial number of farmers' (70.3%) were growing *rajmash* as a rainfed crop. Data of farming practice across thirty two locations (Table 3.1 and 3.2) revealed that when farmers' were asked about the source of irrigation system, it was found that crop was mostly grown under rainfed conditions, however at Village Warnov (40.7%) and Longate (43.3%) areas of District Kupwara, a notable land of farmers' under irrigated conditions. However at Village Jaban in District Bandipora the area under *rajmash* was maximum rainfed (92.5%) while as at Village Butgund in District Kupwara the maximum area (48%) was under assured irrigation. The comparison is significant between the above two (Rainfed versus assured) as the calculated value of t-test comes out to be 6.6 (t tabulated= 1.697 at 30 d.f.).

4.1.2.4 Biotic stresses (disease resistance verses insect pest and weeds)

Among all biotic stresses like diseases, pests, weeds etc. diseases especially BCMV was identified as a major production constraint by about 68.27% farmers'. Among the biotic stresses and in this regard disease resistance was compared with insect pest and weeds. Of the total, only 32.73% of farmers'

opined that insect pest and weeds pose a threat to the production of *rajmash*. The comparison is significant as the calculated value of t-test comes out to be 4.6 (t tabulated= 1.697 at 30 d.f.) revealing that the resistance to diseases is to be taken under consideration more than the insect and resistance from weeds.

4.1.2.5 Abiotic stresses (drought tolerance vs cold tolerance)

The major abiotic production constraint which hampers the *rajmash* production is drought tolerance (73.10%). Among the abiotic stresses drought tolerance was compared with cold tolerance. At Village Kaward in District Kupwara about 90% of the farmers were of the opinion that, the *rajmash* varieties should be more drought resistant than that of the cold resistance (only 10% opined in this favour). The comparison is significant as the calculated value of t-test comes out to be 5.5 (t tabulated= 1.697 at 30 d.f.) revealing that the drought tolerance is to be taken under consideration more than the cold tolerance.

4.1.2.6 Yield (grain yield verses pod load and others)

Among the yield attribute and in this regard grain yield was compared with pod load and others. In this case substantial number of farmers (54.41%) pointed out that it is grain yield which is more preferred over other traits like culinary and cooking. The comparison is non-significant between grain yield verses pod load and others, revealing that the variety with good yield, the attributes like number of pods per plant, pod load and others are also taken into consideration.

4.1.3 Understanding farmers' varietal preferences

4.1.3.1 Source of seed (Farmer own seed versus Market + institution)

Regarding the source of seed, significant number of the selected farmers' reported that they use their own seed (78.10%) for production of *rajmash* at all the three districts. It is because of the limited supply of seed from all the government and semi-government/private sources which compels the farmer to use his own saved seed. At Village Kohru in District Kupwara, 93.3 per cent of farmers' were

of the opinion that they use their own saved seed to raise the new crop and at Village Potasa in District Baramulla 60 per cent of farmers' were of the opinion that they raise the new crop from the seed derived from other sources. The comparison is significant based on the value of t-test.

4.1.3.2 Colour of seed (small red versus others (Kidney white + kidney red + white navy + chocolate black))

Regarding colour of seed, 50 per cent of the farmers' favoured small red varieties as demand for such type of seed of *rajmash* at market is more. Although kidney red and other coloured varieties (50%) of *rajmash* are also preferred almost at all locations to a varying extent. The comparison based on t-test is non-significant, indicating that across locations in spite of preference of farmers' towards small red other varieties of *rajmash* were also preferred to a considerable extent. The t-test calculated value comes out to be 0.4 (t tabulated= 1.697 at 30 d.f.).

4.1.3.3 Seed coat pattern (plain versus mottled)

Farmers' almost across all location like plain seed coat (71.83%) and this trait scored highest as compared to mottled. However in practical utility both the seed types are consumed by the farmers' in a bigger proportion (Table 3.1 and 3.2). The comparison is significant based on the value of t-test.

4.1.3.4 Seed shape (Kidney versus oval + Cuboidal + Cylindrical)

Regarding seed type, 50 percent of the farmers' favoured kidney shaped beans genotypes, as it is socially and ecologically fit under their production system followed by oval. Cuboidal and cylindrical types were disliked by most of farmers'. The comparison is non-significant based on the value of t-test, indicating that the farmers' preference towards seed shape vary considerably across locations.

4.1.3.5 Maturity (Earliness versus uniform maturity)

Maturity is one of the most important traits in *rajmash*. Earliness was

more preferred by farmers' across all the locations as 87.04 percent of the farmers opined in this favour, because they want to save the crop from the terminal drought, which effects the crop to a considerable limit, at later stages of growth. From the Table, t-test value revealed that there is a significant difference between Earliness and uniform maturity indicating that the earlier varieties are more preferred over the varieties with uniform harvest. The comparison based on the t-test is significant.

4.1.3.6 Market (seed size verses seed shape and others)

The market attribute of *rajmash* was assessed through seed size, shape and others and in this regard seed size was compared with seed shape and others. It was seed size (58.71 percent of farmers opined in this favour) which catches the attention of the famers than seed shape and others. The comparison was significant as the calculated value of t-test comes out to be 2.2 (t tabulated= 1.697 at 30 d. f.) revealing that the farmers' perception was more towards the variety with greater seed size compared to a variety with lower size of seeds.

4.1.3.7 Culinary traits (Taste versus cooking time + Swelling/ Flatulence and others)

The perceptions of farmers' regarding the nature of culinary traits revealed that significant number of farmers' (56.20%) preferred *rajmash* with good swelling character and a variety that cooks at a considerable short period of time with good taste. The comparison (Table 3.3 and 3.4) was non-significant based on the value of t-test, revealing that the farmers' perception was diverse towards the *rajmash* as for as the culinary traits of a variety is concerned.

The t-test comparison analysis of participatory rural appraisal (PRA) comes out to be significant for most of the traits compared. In general the t-test revealed that most of farmers' across all thirty two locations cultivate beans as pulse crop, as a mixed crop mostly with maize and the seed to be used to raise the next season crop for cultivation was farmers' own saved seed under rain-fed conditions. Due to a limited production of the seed by the government and private

Table-3.1: Participatory Rural Appraisal (PRA) at 32 different locations of three districts (Kupwara, Baramulla and Bandipora) for understanding farmers' perceptions and preferences about common bean varieties

Location	N	R	Ranking		Farming practice		Irrigation system		Source of seed		Colour of seed		Seed coat pattern		Seed shape	
			1 st	Other (1 st)	sole crop	Mixed crop	Assured	Rainfed	Farmers' own seed	Institution/ other	Small red	Kidney red/ others	Plain	Mottled	Kidney	Oval/ others
Warnov (Kupwara)	30	27	92.5	7.4	14.8	85.1	40.7	59.2	81.4	18.5	44.4	55.5	59.2	40.7	48.1	51.8
Anwarabad	25	20	85.0	15.0	15.0	85.0	40.0	60.0	90.0	10.0	50.0	50.0	70.0	30.0	60.0	40.0
Aafan	35	30	93.3	6.6	20.0	80.0	40.0	60.0	80.0	20.0	46.6	53.3	63.3	36.6	46.6	53.3
Kaward	38	30	90.0	10.0	23.3	76.6	33.3	66.6	83.3	16.6	46.6	53.4	56.6	43.3	50.0	50.0
Warnow –B	40	30	96.6	3.3	16.6	83.3	43.3	56.6	76.6	23.3	36.6	63.3	53.3	46.6	33.3	66.6
Sewar	25	20	85.0	15.0	10.0	90.0	40.0	60.0	85.0	15.0	45.0	55.0	75.0	25.0	55.0	45.0
Longte	35	30	76.6	23.3	16.6	83.3	43.3	56.6	73.3	26.6	53.3	46.6	60.0	40.0	46.6	53.3
Shanoo	30	25	88.0	12.0	12.0	88.0	40.0	60.0	72.0	28.0	56.0	44.0	80.0	20.0	52.0	48.0
Shutgund	25	20	80.0	20.0	15.0	85.0	40.0	60.0	70.0	30.0	55.0	45.0	75.0	25.0	55.0	45.0
Butgund	30	25	72.0	28.0	16.0	84.0	48.0	52.0	68.0	32.0	52.0	48.0	68.0	32.0	48.0	52.0
Kohru	20	15	80.0	20.0	33.3	66.0	40.0	60.0	93.3	6.6	60.0	40.0	66.6	33.3	46.6	53.3
Hajibal (Baramulla)	25	20	85.0	15.0	35.0	65.0	25.0	75.0	80.0	20.0	56.0	44.0	70.0	30.0	40.0	60.0
Waniloo	10	8	87.5	12.5	50.0	50.0	25.0	75.0	62.5	37.5	62.5	37.5	75.0	25.0	62.5	37.5
Namalnar	30	25	80.0	20.0	32.0	68.0	16.0	84.0	72.0	28.0	48.0	52.0	60.0	40.0	40.0	60.0
Shalgam	30	27	81.4	18.5	25.9	74.0	18.5	81.4	74.0	25.9	40.7	59.2	66.6	33.3	40.7	59.2
Warpora	27	20	85.0	15.0	25.0	75.0	20.0	80.0	85.0	15.0	50.0	50.0	80.0	20.0	50.0	50.0
Fajpora	23	20	75.0	25.0	35.0	65.0	30.0	70.0	80.0	20.0	50.0	50.0	75.0	25.0	45.0	55.0

() the parenthesis shows districts below which all villages are included in this, till next district may start; N = Total No. of farmers; R = Total No. of respondents

Table-3.2: Participatory Rural Appraisal (PRA) at 32 different locations of three districts (Kupwara, Baramulla and Bandipora) for understanding farmers' perceptions and preferences about common bean varieties

Location	N	R	Ranking		Farming practice		Irrigation system		Source of seed		Colour of seed		Seed coat pattern		Seed shape	
			1 st	Other (1 st)	sole crop	Mixed crop	Assured	Rainfed	Farmers' own seed	Institution/ other	Small red	Kidney red/ others	Plain	Mottled	Kidney	Oval/ others
Rohama (Baramulla)	35	30	76.6	23.3	26.6	73.3	43.3	56.6	73.3	26.6	50.0	50.0	70.0	30.0	46.6	53.3
Sarpora	26	20	80.0	20.0	20.0	80.0	40.0	60.0	70.0	30.0	50.0	50.0	85.0	15.0	50.0	50.0
Shutloor	40	30	86.6	13.3	13.3	86.6	30.0	70.0	66.6	33.3	46.6	53.4	60.0	40.0	50.0	50.0
Khushipora	45	35	85.9	14.2	14.2	85.7	37.1	62.8	68.5	31.4	45.7	54.2	77.0	22.8	51.4	48.5
Potosa	15	10	70.0	30.0	30.0	70.0	40.0	60.0	60.0	40.0	60.0	40.0	70.0	30.0	60.0	40.0
Sumlar (Bandipora)	15	13	76.9	23.0	15.3	84.6	23.0	76.9	76.9	23.0	53.8	46.0	76.9	23.0	38.4	61.5
Chuntimulla	20	15	80.0	20.0	20.0	80.0	13.3	86.6	86.6	13.3	60.0	40.0	80.0	20.0	46.6	53.3
Arin	30	25	72.0	28.0	28.0	72.0	12.0	88.0	80.0	20.0	56.0	44.0	84.0	16.0	48.0	52.0
Qudar	35	30	73.3	26.6	10.0	90.0	10.0	90.0	86.6	13.3	53.3	46.6	80.0	20.0	50.0	50.0
Jaban	30	27	85.9	14.8	14.8	85.1	7.4	92.5	85.1	14.8	59.2	40.7	81.4	18.5	55.5	44.4
Malangam	25	22	81.8	18.1	18.1	81.8	13.6	86.3	90.9	9.0	63.6	36.3	72.7	27.2	59.0	40.9
Malangam-B	30	25	92.0	8.0	12.0	88.0	20.0	80.0	92.0	8.0	60.0	40.0	80.0	20.0	56.0	44.0
Malangam-C	15	12	83.3	16.6	16.6	83.3	33.3	66.6	66.6	33.3	66.6	33.3	66.6	33.3	50.0	50.0
Aloosa	30	25	80.0	20.0	16.0	84.0	28.0	72.0	84.0	16.0	56.0	44.0	76.0	24.0	60.0	40.0
Quolmuqam	25	20	70.0	30.0	10.0	90.0	15.0	85.0	85.0	15.0	60.0	40.0	85.0	15.0	65.0	35.0
t(p≤0.05) at 30 d.f.			9.95		6.9		6.6		6.978		0.45		5.486		0.08	

N = Total No. of farmers; R = Total No. of respondents

Table-3.3: Participatory Rural Appraisal (PRA) at 32 different locations of three districts (Kupwara, Baramulla and Bandipora) for understanding farmers' perceptions and preferences about common bean varieties

Location	N	R	Maturity		Biotic stresses		Abiotic stresses		yield		Market		Culinary traits	
			Earliness	Uniform harvest	Disease resistance	Insect pests/weed	Drought tolerance	Cold tolerance/others	Grain yield	Pod load/others	Seed size	Seed shape/others	Swelling	Cooking time/ taste
Warnov (Kupwara)	30	27	92.5	7.4	62.9	37.0	88.8	11.1	37.0	62.9	51.8	48.1	48.1	51.8
Anwarabad	25	20	85.0	15.0	65.0	35.0	80.0	20.0	40.0	60.0	55.0	45.0	60.0	40.0
Aafan	35	30	90.0	10.0	66.6	33.3	80.0	20.0	43.3	56.6	60.0	40.0	50.0	50.0
Kaward	38	30	86.6	13.3	73.3	26.6	90.0	10.0	46.6	53.3	66.6	33.3	53.3	46.6
Warnow-B	40	30	83.3	16.6	70.0	30.0	83.3	16.6	43.3	56.6	73.3	26.6	46.6	53.3
Sewar	25	20	80.0	20.0	70.0	30.0	80.0	20.0	50.0	50.0	60.0	40.0	55.0	45.0
Longte	35	30	90.0	10.0	60.0	40.0	80.0	20.0	40.0	60.0	56.6	43.3	43.3	56.6
Shanoo	30	25	80.0	20.0	64.0	36.0	84.0	16.0	48.0	52.0	64.0	36.0	44.0	56.0
Shutgund	25	20	80.0	20.0	70.0	30.0	80.0	20.0	60.0	40.0	70.0	30.0	50.0	50.0
Butgund	30	25	84.0	16.0	68.0	32.0	84.0	16.0	52.0	48.0	64.0	36.0	44.0	56.0
Kohru	20	15	73.3	26.6	60.0	40.0	73.3	26.6	53.3	46.6	53.3	46.6	53.3	46.6
Hajibal (Baramulla)	25	20	90.0	10.0	70.0	30.0	70.0	30.0	60.0	40.0	50.0	50.0	40.0	60.0
Waniloo	10	8	87.5	12.5	62.5	37.5	62.5	37.5	62.5	37.5	62.5	37.5	12.5	87.5
Namalnar	30	25	92.0	8.0	64.0	36.0	64.0	36.0	60.0	40.0	60.0	40.0	40.0	60.0
Shalgam	30	27	92.5	7.4	74.0	25.9	77.7	22.2	59.2	40.7	66.6	33.3	40.7	59.2
Warpora	27	20	95.0	5.0	75.0	25.0	75.0	25.0	60.0	40.0	60.0	40.0	45.0	55.0
Fajpora	23	20	85.0	15.0	65.0	35.0	70.0	30.0	55.0	45.0	50.0	50.0	40.0	60.0

Table-3.4: Participatory Rural Appraisal (PRA) at 32 different locations of three districts (Kupwara, Baramulla and Bandipora) for understanding farmers' perceptions and preferences about common bean varieties

Location	N	R	Maturity		Biotic stresses		Abiotic stresses		yield		Market		Culinary traits	
			Earliness	Uniform harvest	Disease resistance	Insect pests/weed	Drought tolerance	Cold tolerance/others	Grain yield	Pod load/others	Seed size	Seed shape/others	Swelling	Cooking time/taste
Rohama (Baramulla)	35	30	93.3	6.6	53.3	46.6	73.3	26.6	60.0	40.0	66.6	33.3	46.6	53.3
Sarpora	26	20	95.0	5.0	70.0	30.0	65.0	35.0	60.0	40.0	55.0	45.0	40.0	60.0
Shutloor	40	30	96.6	3.3	50.0	50.0	73.3	26.6	56.6	43.3	60.0	40.0	46.6	53.3
Khushipora	45	35	91.4	8.5	57.1	42.8	77.1	22.8	65.7	34.2	68.5	31.4	45.7	54.2
Potosa	15	10	80.0	20.0	60.0	40.0	50.0	50.0	60.0	40.0	50.0	50.0	40.0	60.0
Sumlar (Bandipora)	15	13	76.9	23.0	76.9	23.0	61.5	38.4	53.8	46.1	46.1	53.8	46.1	53.8
Chuntimulla	20	15	86.6	13.3	80.0	20.0	60.0	40.0	53.3	46.6	46.6	53.3	46.6	53.3
Arin	30	25	92.0	8.0	72.0	28.0	64.0	36.0	68.0	32.0	60.0	40.0	40.0	60.0
Qudar	35	30	90.0	10.0	83.3	16.6	80.0	20.0	60.0	40.0	60.0	40.0	40.0	60.0
Jaban	30	27	88.8	11.1	74.0	25.9	66.6	33.3	55.5	44.4	51.8	48.1	40.7	59.2
Malangam	25	22	86.3	13.6	72.7	27.2	72.7	27.2	63.6	36.3	54.5	45.4	45.4	54.5
Malangam –B	30	25	88.0	12.0	72.0	28.0	72.0	28.0	52.0	48.0	52.0	48.0	48.0	52.0
Malangam –C	15	12	75.0	25.0	66.6	33.3	66.6	33.3	50.0	50.0	50.0	50.0	50.0	50.0
Aloosa	30	25	88.0	12.0	76.0	24.0	64.0	36.0	52.0	48.0	56.0	44.0	44.0	56.0
Quolmuqam	25	20	90.0	10.0	80.0	20.0	70.0	30.0	60.0	40.0	60.0	40.0	50.0	50.0
t(p≤0.05) at 30 d.f.			8.3		4.6		5.5		0.9		2.2		1.4	

sector, it doesn't meet the requirements of the farmer, which in turn compels the farmer to use his own saved seed because of compulsion. The t-test value also revealed that small red kidney shaped seed were preferred by *rajmash* cultivators across all locations. Plain and early maturing varieties with good swelling capacity, less cooking time and tasty varieties were most preferred.

4.2 Preferential scoring

Participatory varietal selection was carried out in three districts, by selecting two villages in each district in the form of farm walks and focus group discussions. Farm walk was done when pods were at edible 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 (white card for preferred genotype and yellow for non-preferred genotype).

Evaluation of Mother trials through farmer's preferential ranking was carried out at six locations (two at each district). At the time of pod maturity when *rajmash* pods were at edible stage, Focal Group Discussions (FGD) and the differences in farmer specified traits were discernible, 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.

4.2.1 Preferential ranking of pole type of *rajmash*

Thirty one genotypes were selected from the material and was laid at four locations in three districts namely Village Warnov in District Kupwara, Village Hajibal in District Baramulla, Village Sumlar in District Bandipora and Regional Research Station, Wadura, Sopore. The farmers' responded overwhelmingly through votes against a particular variety, the number of the farmers' that participated in voting was 14, 16, 10 and 15 respectively at the four locations. There were many genotypes which carry the farmers' attention but few were most

Table-4.1: Farmers' preference ranking of different test varieties (Pole Type) of common bean in mother trails at four locations

Preferential Scoring at Hajibal Tangmarg Baramulla				
Genotypes	Total No. of farmers' (16)			Rank
	Positive votes	Negative votes	Preference score	
WB-38	14	2	0.75**	3
WB-222	10	6	0.25	7
WB-143	12	4	0.5	6
WB-184	9	7	0.12	8
WB-158	13	3	0.62	4
WB-83**	16	0	01	1
WB-230	7	9	-0.12	9
WB-255	2	14	-0.75	14
WB-257	13	3	0.62	5
WB-258**	15	1	0.87	2
WB-243	6	10	-0.25	10
WB-258-1	7	9	-0.12	9
WB-206	5	11	-0.37	11
WB-261	4	12	-0.5	12
WB-358	7	9	-0.12	9
WB-128	10	6	0.25	7
WB-224	4	12	-0.5	12
WB-240	5	11	-0.37	11
WB-1137	10	6	0.25	7
WB-461	12	4	0.5	6
WB-443	2	14	-0.75	14
WB-409	10	6	0.25	7
WB-411	12	4	0.5	6
WB-08	4	12	-0.5	12
WB-450	14	2	0.75	3
WB-370	6	10	-0.25	10
WB-400	4	12	-0.5	12
WB-1012	5	11	-0.37	11
WB-330	3	13	-0.62	13
WB-1115	2	14	-0.75	14
WB-1011**	14	2	0.75	3

Table-4.2 : Preferential scoring at Warnov, Kupwara

Genotypes	Total No. of farmers' (14)		Preference score	Rank
	Positive votes	Negative votes		
WB-38	11	03	0.57	4
WB-143**	12	02	0.71	3
WB-83**	14	0	01	1
WB-184	6	08	-0.14	6
WB-158	6	08	-0.14	6
WB-258**	13	01	0.85	2
WB-230	5	09	-0.28	7
WB-255	1	13	-0.85	11
WB-257	6	8	-0.14	6
WB-222**	12	2	0.71	3
WB-243	3	11	0.57	4
WB-258-1	10	04	0.42	5
WB-206	3	11	-0.57	9
WB-261	1	13	-0.85	11
WB-358	4	10	-0.42	8
WB-128	3	11	-0.57	9
WB-224	2	12	-0.71	10
WB-240	4	10	-0.42	8
WB-1137	3	11	-0.57	9
WB-461**	12	02	0.71	3
WB-443	6	8	-0.14	6
WB-409	3	11	-0.57	9
WB-411	2	12	-0.71	10
WB-1011**	12	02	0.71	3
WB-1012	10	4	0.42	5
WB-370	6	08	-0.14	6
WB-400**	12	02	0.71	3
WB-450**	12	02	0.71	3
WB-330	2	12	-0.71	10
WB-1115	4	10	-0.42	8
WB-8	10	04	0.42	5

Table-4.3 : Preferential scoring at Sumlar, Bandipora

Genotypes	Total No. of farmers' (10)			
	Positive votes	Negative votes	Preference score	Rank
WB-38	8	2	0.6	3
WB-83**	10	0	1	1
WB-258**	9	1	0.8	2
WB-184	6	4	0.2	5
WB-158	8	2	0.6	3
WB-143	7	3	0.4	4
WB-230	4	6	-0.2	7
WB-255	5	5	0	6
WB-257	6	4	0.2	5
WB-222	8	2	0.6	3
WB-243	5	5	0	6
WB-258-1	7	3	0.4	4
WB-206	4	6	-0.2	7
WB-261	3	7	-0.4	8
WB-358	4	6	-0.2	7
WB-128	6	4	0.2	5
WB-224	4	6	-0.2	7
WB-8	7	3	0.4	4
WB-1137	6	4	0.2	5
WB-450	8	2	0.6	3
WB-443	5	5	0	6
WB-409	4	6	-0.2	7
WB-411	3	7	-0.4	8
WB-1011**	9	1	0.8	2
WB-1012	7	3	0.4	4
WB-370	6	4	0.2	5
WB-400	4	6	-0.2	7
WB-461	3	7	-0.4	8
WB-330	2	8	-0.6	9
WB-1115	1	9	-0.8	10
WB-240	4	6	-0.2	7

Table-4.4: Preferential ranking at Regional Research Station, Wadura, Sopore

Genotypes	Total No. of farmers' (15)			
	Positive votes	Negative votes	Preference score	Rank
WB-38	12	3	0.6	2
WB-222	10	5	0.3	4
WB-143	11	4	0.4	3
WB-184	9	6	0.2	5
WB-158**	13	2	0.7	2
WB-258**	14	1	0.8	1
WB-230	7	8	-0.06	6
WB-255	2	13	-0.7	11
WB-257**	13	2	0.7	2
WB-83**	14	1	0.8	1
WB-243	6	9	-0.2	7
WB-258-1	7	8	-0.06	6
WB-206	5	10	-0.3	8
WB-261	4	11	-0.4	9
WB-358	7	8	-0.06	6
WB-128	10	5	0.3	4
WB-224	4	11	-0.4	9
WB-240	5	10	-0.3	8
WB-1137	10	5	0.3	4
WB-461	12	3	0.6	2
WB-443	2	13	-0.73	11
WB-409	10	5	0.3	4
WB-411	12	3	0.6	2
WB-1011	4	11	-0.4	9
WB-1012**	14	1	0.8	1
WB-370	6	9	-0.2	7
WB-400	4	11	-0.4	9
WB-450	5	10	-0.3	8
WB-330	3	12	-0.6	10
WB-1115	2	13	-0.7	11
WB-8**	14	1	0.8	1

Table-4.5: Cumulative/average ranks of pole type of genotypes over four locations

Genotype	Individual ranks			Research Station	Cumulative rank	Average of ranks	Pooled preference score
	Warnov (Kupwara)	Hajibab (Baramulla)	Sumlar (Bandipora)				
WB-38	4	3	3	2	12	3	2.5
WB-83	3	7	1	4	15	3.7	2.3
WB-143	1	6	2	3	12	3	2.6
WB-184	6	8	5	5	24	6	0.8
WB-158	6	4	3	2	15	3.7	1.3
WB-109	2	1	4	1	8	2	2.6
WB-230	7	9	7	6	29	7.2	-0.6
WB-255	11	14	6	11	42	10.5	-2.3
WB-257	6	5	5	2	18	4.5	1.3
WB-222	3	2	3	1	9	2.2	3.6
WB-243	4	10	6	7	27	6.7	0.1
WB-258-1	5	9	4	6	24	6	0.6
WB-206	9	11	7	8	35	8.7	-1.4
WB-261	11	12	8	9	40	10	-2.2
WB-358	8	9	7	6	30	7.5	-0.8
WB-128	9	7	5	4	25	6.2	0.2
WB-224	10	12	7	9	38	9.5	-1.8
WB-240	8	11	4	8	31	7.7	-0.7
WB-1137	9	7	5	4	25	6.2	0.2
WB-461	3	6	3	2	14	3.5	2.4
WB-443	6	14	6	11	37	9.2	-1.6
WB-409	9	7	7	4	27	6.7	-0.1
WB-411	10	6	8	2	26	6.5	-0.01
WB-1011	3	12	2	9	26	6.5	0.3
WB-1012	5	3	4	1	13	3.2	2.7
WB-370	6	10	5	7	28	7	-0.3
WB-400	3	12	7	9	31	7.7	-0.4
WB-450	3	11	8	8	30	7.5	-0.2
WB-330	10	13	9	10	42	10.5	-2.5
WB-1115	8	14	10	11	43	10.7	-2.7
WB-8	5	3	7	1	16	4	1.8

promising lines. At the village Warnov Kupwara highest preferential scoring i.e. lowest rank value was recorded on WB-83(1) followed by WB-258 (2), WB-143(3), WB-222 (3), and WB-38(4) (Table-4.2). The lowest preference was recorded for WB-224 (-0.71) followed by WB-330 (-0.71). Similarly at village Hajibal in Baramulla district (Table-4.1) maximum scoring was recorded for WB-83 (1) followed by WB-258 (2), WB-38 (3), WB-1011 (4), and WB-450 (4). At village Sumlar Bandipora district (Table-4.3) WB-83 (1), WB-258 (2), WB-1011 (3), WB-450 (4), WB-38 (5) received maximum number of votes as preferred by the farmers'. At Research Station, Wadura, Sopore the genotype WB-83 (1), WB-258 (1), WB-1012 (1), have maximum preferential scoring followed by WB-38(2), WB-143(3) (Table 4.4).

Table-4.5 shows the summation of ranks and pooled preference data for different test entries as collected from four mother trials. Lowest cumulative rank of a particular genotype with highest pooled preference indicates that the variety is the most preferred one. The variety WB-258 with mean preference rank of 3.2, WB-38 identified as second best (2.4) followed by WB-1011 (1.9), WB-222 (1.8) and WB-83 (1.6). Table-4.5 clearly shows that WB-184, WB-258-1 and WB-330, WB-255 were statistically at par in term of rank summation index. The lowest preference was recorded for WB-1115 followed by WB-330.

The reasons for the preference were related to many traits including seed size and colour, early maturity, high seed yield, taste and swelling and free from diseases as per the interviews.

4.2.2 Preferential ranking of bush type of *Rajmash*

Twenty three genotypes were selected from the material and was laid at four locations in three districts namely Village Langate in District Kupwara, Village Rohama in District Baramulla, Village Malangam in District Bandipora and Regional Research Station Wadura Sopore. The farmers' responded through votes in favour or against a particular variety (as each farmer was given two cards

one yellow for preferred variety and other green for non-preferred variety). The number of the farmers' who participated in the voting were 13, 15, 10 and 12 respectively at the four locations. There were many genotypes which carry the farmers' attention but few were most promising lines. At the village Longate Kupwara highest preferential scoring i.e. lowest rank value was recorded on WB-185(1) followed by WB-195 (2), Shalimar Rajmash-1(3), WB-966 (3), and WB-223(4) (Table-5.1). The lowest preference was recorded for WB-479 followed by WB-490. Similarly at village Rohama in Baramulla district (Table-5.2) maximum scoring was recorded for WB-147 (1), 185, Shalimar Rajmash-1 followed by WB-195 (2), WB-966 (2) and WB-209 (3). At village Malangam Bandipora district (Table-5.3) WB-185 (1), WB-147 (2), Shalimar Rajmash-1 (2), WB-966 (2), WB-195 (3) received maximum number of votes as preferred by the farmers'. At Research Station, Wadura, Sopore (Table 5.4) the genotype WB-185 (1), WB-147 (2), WB-209 (2), have maximum preferential scoring followed by Shalimar Rajmash-1 (2), WB-966(3).

Table-5.5 shows the summation of ranks and pooled preference data for different test entries as collected from four mother trials. Lowest cumulative rank of a particular genotype with highest pooled preference indicates that the variety is the most preferred one. The variety WB-185 with mean preference rank of 3.8, WB-147 identified as second best (3.3) followed by WB-966 (3.05), Shalimar Rajmash-1 (3.1) and WB-195 (2.3). Table-5.5 clearly shows that WB-22, WB-209 and WB-223 were statistically at par in term of rank summation index. The lowest preference was recorded for WB-490(-2.5) followed by WB-54(-2.4).

The reasons for the preference were related to many traits including seed size and colour, early maturity, high seed yield, taste and swelling and free from diseases as per the interviews.

Table-5.1: Farmers' preference ranking of different test varieties (Bush Type) of common bean in mother trails at four locations

Preferential scoring at Longate Baramulla				
Genotypes	Total No. of farmers' (13)			Rank
	Positive votes	Negative votes	Preference score	
WB-22	8	5	0.2	6
WB-195**	12	1	0.8	2
WB-147	9	4	0.3	5
WB-185**	13	0	1	1
WB-209	6	7	-0.07	8
WB-223	10	3	0.5	4
WB-249	9	4	0.3	5
WB-191	5	8	-0.2	9
WB-192	6	7	-0.07	8
WB-634	9	4	0.3	5
WB-462	3	10	-0.5	11
WB-490	4	9	-0.3	10
WB-1031	6	7	-0.07	8
WB-569	8	5	0.2	6
WB-330	9	4	0.3	5
SR-1**	11	2	0.6	3
WB-479	4	9	-0.3	10
WB-54	5	8	-0.2	9
WB-489	9	4	0.3	5
WB-487	7	6	0.07	7
WB-852	8	5	0.2	6
WB-966**	11	2	0.6	3
WB-885	10	3	0.5	4
WB-1011	4	11	-0.4	9
WB-1012**	14	1	0.8	1
WB-370	6	9	-0.2	7
WB-400	4	11	-0.4	9
WB-450	5	10	-0.3	8
WB-330	3	12	-0.6	10
WB-1115	2	13	-0.7	11
WB-8**	14	1	0.8	1

Table-5.2 : Preferential ranking at Rohama, Baramulla

Genotypes	Total No. of farmers' (15)			
	Positive votes	Negative votes	Preference score	Rank
WB-22	10	5	0.3	5
WB-147**	14	1	0.8	1
WB-195**	13	2	0.7	2
WB-185**	14	1	0.8	1
WB-209*	12	3	0.6	3
WB-223	10	5	0.3	5
WB-249	11	4	0.4	4
WB-191	12	3	0.6	3
WB-192	6	9	-0.2	9
WB-634	10	5	0.3	5
WB-462	5	10	-0.3	10
WB-490	2	13	-0.7	12
WB-1031	4	11	-0.4	11
WB-569	8	7	0.06	7
WB-330	9	6	0.2	6
SR-1**	14	1	0.8	1
WB-479	4	11	-0.4	11
WB-54	2	13	-0.7	12
WB-489	11	4	0.4	4
WB-487	7	8	-0.06	8
WB-852	8	7	0.06	7
WB-966**	13	2	0.7	2
WB-885	11	4	0.4	4

Table-5.3 : Preferential ranking at Malangam, Bandipora

Genotypes	Total No. of farmers' (10)			
	Positive votes	Negative votes	Preference score	Rank
WB-22	7	3	0.4	4
WB-147**	9	1	0.8	2
WB-195**	8	2	0.6	3
WB-185**	10	0	1	1
WB-209	6	4	0.2	5
WB-223	7	3	0.4	4
WB-249*	8	2	0.6	3
WB-191	6	4	0.2	5
WB-192	4	6	-0.2	7
WB-634	7	3	0.4	4
WB-462	3	7	-0.4	8
WB-490	2	8	-0.6	9
WB-1031	4	6	-0.2	7
WB-569	6	4	0.2	5
WB-330	7	3	0.4	4
SR-1**	9	1	0.8	2
WB-479	2	8	-0.6	9
WB-54	1	9	-0.8	10
WB-489	8	2	0.6	3
WB-487	5	5	0	6
WB-852	6	4	0.2	5
WB-966**	9	1	0.8	2
WB-885	8	2	0.6	3

Table-5.4: Preferential ranking at Regional Research Station, Wadura, Sopore

Genotypes	Total No. of farmers' (12)			
	Positive votes	Negative votes	Preference score	Rank
WB-22	10	2	0.6	3
WB-147**	11	1	0.8	2
WB-195	10	2	0.6	3
WB-185**	12	0	1	1
WB-209**	11	1	0.8	2
WB-223	8	4	0.3	5
WB-249	9	3	0.5	4
WB-191**	11	1	0.8	2
WB-192	7	5	0.1	6
WB-634	10	2	0.6	3
WB-462	2	10	-0.6	10
WB-490	1	11	-0.8	11
WB-1031	3	9	-0.5	9
WB-569	6	6	0	7
WB-330	7	5	0.1	6
SR-1**	11	1	0.8	2
WB-479	2	10	-0.6	10
WB-54	2	10	-0.6	10
WB-489	9	3	0.5	4
WB-487	5	7	-0.1	8
WB-852	7	5	0.1	6
WB-966**	11	1	0.8	2
WB-885	10	2	0.6	3

Table-5.5: Cumulative/average ranks of bush type of genotypes over four locations

Genotype	Individual ranks				Cumulative rank	Average of ranks	Pooled preference score
	Longate (Kupwara)	Rohama (Baramulla)	Malangam (Bandipora)	Research Station			
WB-22	6	5	4	3	18	4.5	1.6
WB-147**	2	1	2	2	7	1.7	3.3
WB-195**	5	2	3	3	13	3.2	2.3
WB-185**	1	1	1	1	4	1	3.8
WB-209	8	3	5	2	18	4.5	1.5
WB-223	4	5	4	5	18	4.5	1.6
WB-249	5	4	3	4	16	4	1.9
WB-191	9	3	5	2	19	4.7	1.4
WB-192	8	9	7	6	30	7.5	-0.3
WB-634	5	5	4	3	17	4.2	1.7
WB-462	11	10	8	10	39	9.7	-1.9
WB-490	10	12	9	11	42	10.5	-2.5
WB-1031	8	11	7	9	35	8.7	-1.2
WB-569	6	7	5	7	25	6.2	0.4
WB-330	5	6	4	6	21	5.2	1.1
SR-1**	3	1	2	2	8	2	3.1
WB-479	10	11	9	10	40	10	-2.1
WB-54	9	12	10	10	41	10.2	-2.4
WB-489	5	4	3	4	16	4	1.9
WB-487	7	8	6	8	29	7.2	-0.1
WB-852	6	7	5	6	24	6	0.6
WB-966**	3	2	2	2	9	2.2	3.05
WB-885	4	4	3	3	14	3.5	2.2
WB-1011	3	12	2	9	26	6.5	0.3
WB-1012	5	3	4	1	13	3.2	2.7
WB-370	6	10	5	7	28	7	-0.3
WB-400	3	12	7	9	31	7.7	-0.4
WB-450	3	11	8	8	30	7.5	-0.2
WB-330	10	13	9	10	42	10.5	-2.5
WB-1115	8	14	10	11	43	10.7	-2.7
WB-8	5	3	7	1	16	4	1.8

4.3 Analysis of variance

4.3.1 Analysis of variance of grand mother trial

The analysis of variance of genotypes of grandmother trial (Table-6) revealed that mean squares due to genotypes were highly significant for almost all of the traits indicating existence of genetic difference among Rajmash genotypes. There was substantial variability among pole type of genotypes studied for all traits except plant height and 100 seed weight. However in bush type genotypes variability was studied for all traits except number of pods per plant (Table 6 and Table-7).

4.3.2 Analysis of variance for stability

4.3.2.1 Genotypes

The pooled analysis of variance for stability of genotypes for nine quantitative traits over four environments (Table-6 and Table-7) revealed that mean squares due to genotypes and environments were significant for all the traits studied. The interaction of component genotype $\times$ environment was significant for all traits.

4.4 Stability parameters

Based on the performance of the genotypes, the stability of performance of different traits was worked out. Estimation of the genotype $\times$ 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 $G \times E$ interaction results from the change in the magnitude of different environments or changes in relative ranking of the genotypes. Consistent performance necessarily is not an only index of stability. Stability may be referred to as a measure of predictable performance. 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 $\times$ 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. $G \times E$ 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 significant genotype $\times$ environment interaction reduces the usefulness of genotypic means for identifying superior cultivars.

The presence of genotype $\times$ environment interactions indicate the statistically non-addictiveness of genotypes and environments, which means that differences between genotypes depend on the environment. Existing genotype $\times$ 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 $G \times E$ interactions *per se*, but is only interested in the existence (or non-existence) of $G \times E$ interactions in so far as they lead to different orderings of genotypes in different environments. This concept of $G \times E$ 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).

4.5 Stability analysis and using Eberhart and Russell Model (1966)

During the past several decades, one of the most important advances in biometrical genetics has been the investigation, elucidation and understanding of genotype $\times$ environment interaction. Even though the importance of genotype-environment interaction was recognized well and these were known to be heritable (Jinks and Mather, 1955). The main efforts made by the researchers were aimed to measure this $G \times E$ 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.

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 $G \times E$ 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 $\times$ 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.

The stability of the variety is a major concern for the commercial utilization of the variety over a large scale. For a variety to be stable, meaning the average performance of the variety does not change over environments and locations. The stability factor for a stable variety should be equal to 1(one). There are various models used in biometrical genetics to evaluate the stability. The fact is that the various models are having different methods to calculate for the stability, but the stability ranking of the different genotypes remains same using different models. So it is better to analyze the genotypes by using the Eberhart and Russell model as it easy to handle.

The most desirable property of genotypes for acceptability for commercial cultivation is their stable performance across locations (environments), which also remain the aim of 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 Russell (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 $\times$ environment)] interaction into three components namely; environments (linear), genotype $\times$ 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_{di}^2) 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_{di}^2) estimates indicate average stability of genotypes across different environments, whereas significant b_i and non-significant S_{di}^2 values indicate stability to specific environments. However the significance of S_{di}^2 estimate, irrespective of whether the corresponding b_i estimate is significant or non-significant would suggest that the behaviour of the genotype is unpredictable.

Based on the principle of stability analysis as per the Eberhart and Russell's model (1966), the sum of squares attributed to environment and $G \times E$ interaction is partitioned into three components viz. environmental (linear), genotype $\times$ environment (linear) and deviation from regression (pooled deviation over all the genotypes). The quantification of environments differs from that of Finlay and Wilkinson (1963) in the meaning that all varieties at a site of seasons were regarded by them as 'site mean'. Eberhart and Russell (1966) preferred to measure the environments as deviation of means of all the varieties at a location from the overall mean. They recognized the need for defining environmental index which is independent of the experimental varieties, but is based on experimental factors such as rainfall, temperature or soil fertility. Eberhart and Russell (1966) is a widely used model where regression and deviation from regression are taken for analysing stability of a variety. They recommended growing of varieties in adequate number of environments (covering a full range of possible environmental conditions) so that useful information is available regarding the stability.

Table-6: Analysis of variance of Mother trial for pole type of genotypes

Source of variation	d.f.	Mean sum of squares								
		Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of pods plant ⁻¹	Pod length (cm)	Pod yield plant ⁻¹ (g)	Seeds pod ⁻¹	Seed yield plot ⁻¹ (g)	100-seed weight (g)
Genotype	30	55.05**	91.5**	10.4	279.0**	7.65**	2704.3**	3.5**	597048**	18.56
Replication	2	11.83**	59.51*****	8957.1	263.8**	8.18**	130.2**	1.6**	51119.9**	8.64
Error	240	22.68**	22.70**	2667.3	114.1**	2.12**	946.2**	0.89**	227252**	42.04

Table-6.1: Analysis of variance for stability of different traits in genotypes of common bean (pole type) across four environments

Source of variation	d.f.	Days to 50% flowering	Days to Maturity	Plant height	No. of pods -1 plant	Pod length	Pod yield/plant	Seeds/pod	100 seed weight (g)	Seed yield/plot
Replication with in environments	8	1.5	3.3	0.6	10.3	0.5	6.9	0.07	0.6	133.7
Varieties	30	349.1**	247.9**	13403**	205.6**	7.8**	3976.5**	3.0**	232.7**	98092**
Environment + (Varieties × Environment)	93	17.1	42.5*	11.2	45.6**	0.8	174.5**	0.4	3.07	25967**
Environments	3	9.6**	267.5**	63.9**	29.2	6.4**	2851.1**	2.1**	21.7**	38507**
Varieties × Environment	90	17.3**	35.0**	19.4**	46.1**	6.7**	85.2**	2.3**	2.4**	13997*
Environment (linear)	1	28.8	802.9**	191.7**	87.6**	19.3**	8553.4***	6.3**	65.3***	115521*
Varieties × Environment (linear)	30	6.40	62.2**	10.3	98.8**	0.6	139.2**	0.2	0.8	24530**
Pooled deviation (non linear)	62	22.1**	20.7**	8.6**	19.1**	0.6*	56.4**	0.4**	3.1**	8448**
Pooled error	240	0.71	2.7	0.4	11.4	0.1	1.06	0.07	0.20	57.7
Total	123	98.1	92.3	3277.5	84.6	2.5	1101.8	1.05	59.10	258884

* Significant at p=0.05; ** Significant at p=0.01

4.6 Pole type of trials

4.6.1 Estimation of stability parameters and identification of stable genotypes (as per Eberhart and Russell's Model) of pole type of genotypes

Estimation of stability parameters for different traits viz. morphological (days to 50% flowering, days to maturity, plant height) yield components (pods plant⁻¹, pod length, number of seeds pod⁻¹, 100-seed weight) and yield (pod yield plant⁻¹, seed yield plot⁻¹) across four random environments are presented in the Table-6.1. The stability parameters estimated were mean of the trait ($\bar{X}$), linear regression (b_i) mean square deviation from regression (S_{di}^2), where $\bar{X}$ provides a measure of the performance of a variety as compared to other entries, the b_i and S_{di}^2 values are the measure of the $G \times E$ interaction. The components S_{di}^2 measures predictability and the component b_i measure the stability. In general, if $G \times E$ is non-significant or where this $G \times E$ interaction is either linear or predominantly linear as compared to its non-linear component, the prediction of stability of a genotype over environments become more reliable. As per the Eberhart and Russell's model of stability, the component S_{di}^2 measures predictability and b_i the stability. Stability of a genotype can be predicted more precisely if $G \times E$ interaction and S_{di}^2 value are non-significant.

4.6.1.1 Days to 50% flowering

Estimation of stability parameter for the number of days to 50% flowering is presented in Table-6.2. The mean value ranged from 46.6 (WB-258) to 60.8 (WB-230) and with a population mean ($\bar{X}$) of 48.5 days. The mean performance of all genotypes was highly significant for all traits. The regression coefficient (b_i) was non-significant for all genotypes except few which include WB-143, WB-158, WB-257, WB-222, WB-206, WB-128 and WB-450 and it ranged from -5.2 to 3.3. Thus, all these genotypes were average in stability and either poorly or well adapted to environments. The estimation of mean square deviation from regression (S_{di}^2) was non-significant for all varieties except WB-143, WB-158,

WB-230, WB-222, WB-243, WB-128 and WB-1012 making it possible to predict precisely the stability of most of the genotypes regarding the trait across locations.

4.6.1.2 Days to maturity

The stability parameters b_i and S_{di}^2 along with the mean values for days to maturity are presented in Table-6.2. Days taken to maturity divulged a wide magnitude of variability for the mean performance of the genotypes across the location, which ranged from 83.8 (WB-1137) to 111.5(WB-1115) with a population mean of 93.5 days. The deviation from regression (S_{di}^2) was non-significant for all varieties except WB-255 and WB-261 making it possible to predict precisely the stability of most of the genotypes regarding their maturity across locations. The regression coefficient (b_i) ranged from -0.4 to 5.2. Maximum genotypes revealed significant deviation of regression coefficient significantly <1.0 except WB-255, WB-128, WB-224, WB-240, WB-1115, and WB-8. The genotype WB-38, WB-258, WB-230, WB-258-1, WB-358, WB-1137, WB-461, WB-409, WB-411, WB-400 and WB-450 exhibited earliness as compared to population mean and had regression coefficient significantly <1.0 . These genotypes revealed above average response to stability and are expected to mature earlier even under unfavourable environment. The genotypes WB-184, WB-158, WB-255, WB-206, WB-128, WB-224, WB-240, WB-1115 and WB-8 revealed significantly higher maturity than population mean and their corresponding regression coefficients were also significantly >1.0 , revealing all these genotypes exhibited, below average response to stability and could mature slightly late under favourable conditions.

4.6.1.3 Plant height

The stability parameters b_i and S_{di}^2 along with the mean values for plant height are presented in (Table-6.3) revealed that the tallest genotype was WB-255 (243.3 cm) and shortest WB-243 (103 cm), with the mean plant height ($\bar{X}$) of all the cultivars being 171.4 cm. The difference among the cultivars for this trait was

Table-6.2: Stability parameters for days to 50% flowering and days taken to maturity in varieties of common bean of pole type evaluated across four random environments

Genotypes	Days to 50 % flowering			Days taken to maturity		
	Mean ($\bar{X}$)	b_i	S^2d_i	Mean ($\bar{X}$)	b_i	S^2d_i
WB-38	49.5	3.8	6.2	92.0	0.6	-0.1
WB-83	47.0	2.8	0.5	92.2	0.9	0.8
WB-143	53.0	2.6	8.5	91.4	0.2	4.4
WB-184	53.3	7.7	1.2	97.5	0.3	-2.5
WB-158	50.2	3.3	7.3	99.2	0.3	-0.3
WB-258	46.6	2.9	0.4	90.4	-0.2	0.04
WB-230	60.8	-2.0	9.7	90.1	0.5	-0.05
WB-255	53.1	1.7	6.6	98.6	1.9	17.3
WB-257	51.5	2.9	2.0	90.2	0.1	3.1
WB-222	49.5	3.3	8.9	91.3	0.1	0.3
WB-243	60.0	-0.07	11.2	91.1	0.2	5.4
WB-258-1	60.7	0.3	14.5	88.7	0.5	0.5
WB-206	48.5	3.0	19.5	95.5	0.4	1.3
WB-261	50.2	1.0	4.09	90.6	0.3	10.7
WB-358	59.2	2.7	2.02	87.5	0.7	6.3
WB-128	51.0	3.0	7.9	96.4	2.4	9.2
WB-224	51.0	0.05	0.2	104.8	5.1	40.0
WB-240	60.1	-2.5	13.9	111	4.3	36.8
WB-1137	55.2	1.7	0.1	83.8	-0.1	1.6
WB-461	56.6	-1.3	4.1	84.5	-0.1	4.1
WB-443	55.0	0.07	3.2	90.1	-0.4	2.6
WB-409	51.5	0.5	1.1	84.6	-0.1	4.0
WB-411	53.5	0.2	5.7	87.2	0.1	10.9
WB-1011	60.7	-5.2	12.6	90.8	0.5	3.6
WB-1012	57.0	0.9	7.7	91.5	0.2	4.3
WB-370	47.5	-0.8	11.9	91.5	0.6	18.1
WB-400	52.2	-2.2	1.2	88.2	0.7	-0.8
WB-450	53.5	2.8	1.05	84.4	0.6	0.6
WB-370	53.0	-1.0	4.7	96.4	1.0	9.5
WB-1115	60.2	-3.6	11.5	111.3	5.2	16.8
WB-8	50.4	1.9	29.1	104.5	3.7	12.3
Population mean		48.5			93.5	
SE(m)		2.7			2.6	
SE(b_i)		4.8			0.8	

Table-6.3: Stability parameters for plant height (cm) and number of pods plant⁻¹ in varieties of common bean of pole type evaluated across four random environments

Genotypes	Plant height (cm)			Number of pods plant ⁻¹		
	Mean ($\bar{X}$)	b_i	S^2d_i	Mean ($\bar{X}$)	b_i	S^2d_i
WB-38	151.0	0.4	0.9	22.2	0.7	-6.05
WB-83	180.5	-1.8	0.5	23.4	0.8	-10.7
WB-143	140.7	0.1	4.7	29.4	0.8	-2.02
WB-184	201.2	0.7	4.1	11.4	0.9	-10.5
WB-158	109.3	1.7	1.4	15.7	-0.3	-10.9
WB-258	132.5	2.3	0.7	31.8	1.4	-4.8
WB-230	132.3	2.7	13.1	13.2	0.02	-9.9
WB-255	243.3	2.2	10.0	6.7	-0.4	-10.1
WB-257	108.2	2.0	6.5	13.3	-0.6	-10.9
WB-222	172.3	1.1	-0.1	34.8	0.4	-6.7
WB-243	103.0	1.4	3.2	9.7	-0.2	-10.7
WB-258-1	196.5	1.9	13.6	13.4	-0.1	-10.4
WB-206	194.4	0.8	6.1	17.6	-1.0	-11.1
WB-261	216.3	0.7	0.3	10.2	0.1	-10.6
WB-358	155.5	1.1	10.9	14.3	0.2	-9.5
WB-128	128.1	1.3	0.5	16.0	-0.09	-8.6
WB-224	116.3	1.2	0.9	6.0	-0.3	-11.2
WB-240	194.5	1.1	17.2	10.6	-0.1	-10.8
WB-1137	110.8	2.5	17.5	12.6	-0.4	-10.4
WB-461	140.7	0.8	6.3	21.7	0.1	-10.3
WB-443	174.2	0.1	5.8	10.7	-0.08	-11.3
WB-409	146.7	1.4	2.1	15.5	-0.8	-11.3
WB-411	153.8	1.3	4.2	15.0	0.7	-10.7
WB-1011	176.8	-2.0	11.3	18.9	0.1	-9.1
WB-1012	179.8	0.7	1.3	20.0	-0.2	-11.1
WB-370	185.0	3.1	-0.2	14.1	-0.8	-10.6
WB-400	166.0	2.1	4.7	15.4	-0.8	-11.3
WB-450	120.4	0.7	16.9	16.0	-0.09	-10.7
WB-370	173.6	-1.3	5.3	18.3	0.2	-9.6
WB-1115	126.4	1.0	-0.2	12.8	12.6	5.4
WB-8	239.6	-1.5	21.0	18.0	-0.6	-11.1
Population mean		171.4			17	
SE(m)		1.7			2.5	
SE(b _i)		1.2			2.6	

significant. The estimation of mean square deviation from the regression (S_{di}^2) was non-significant for all genotypes except WB-143, WB-230, WB-255, WB-257, WB-206, WB-240, WB-1137, WB-461, WB-443, WB-411 and WB-370 making it easy to predict stability of this trait over the environments for the genotypes showing non-significant S_{di}^2 . The linear regression value (b_i) ranged -2 to 3.2 and these values were non-significant (no deviation from unity) for many genotypes except WB-370, WB-400, WB-257 and WB-222. All the genotypes showing non-significant S_{di}^2 and b_i were average in stability and poorly or well adapted to the environments depending upon their genetic background.

4.6.1.4 Number of pods plant⁻¹

The mean values and stability parameters b_i and S_{di}^2 for number of pods plant⁻¹ are presented in (Table-6.3). The genotype WB-222 showed highest mean value (34.8) while WB-224 showed the lowest mean value (6) over four random environments with the mean value ($\bar{X}$) of all the genotypes being 17. The estimation of mean square deviation from the regression (S_{di}^2) 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 -0.8 (WB-409) to 12.6 (WB-1115) and these values were non-significant (no deviation from unity) for all genotypes. All the cultivars showing non-significant S_{di}^2 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.

4.6.1.5 Pod length

The pod length of the genotypes ranged from 7 cm (WB-255) to 13.4cm (WB-257) across the locations with population mean of 10.4 cm is presented in (Table-6.4). The magnitude of variability for this trait was broad. The estimation

of mean square deviation from the regression (S_{di}^2) 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 -1.9 to 2.5 and these values were non-significant (no deviation from unity) for all genotypes except WB-492, WB-481, WB-651. All the cultivars showing non-significant S_{di}^2 and b_i were average in stability and poorly or well adapted to the environments. The genotypes WB-143, 83, 184, 230, 257, 243, 258-1, 206, 411 and 1015 have above average mean performance and therefore are better adapted to all the environments.

4.6.1.6 Seeds pod⁻¹

The stability parameters b_i and S_{di}^2 along with the mean values for Seeds panicle⁻¹ are presented in (Table-6.5). The mean value for number of seeds pod⁻¹ ranged from 3 (WB-143) to 7.2 (WB-258-1) with mean ($\bar{X}$) of all the genotypes being 4.7. The non-linear component (S_{di}^2) was non-significant for all the genotypes except WB-38, 83 and WB-258 indicating that the stability for these genotypes (Table-6.5) would be precise. The linear regression (b_i) ranged from -2.1 (WB-400) to 3 (WB-1115) and was found statistically non-significant except genotype WB-38, 83 and 258. 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_{di}^2 values were, by and large, average in stability. However, judging from the mean performance it was observed that the genotypes WB-38, WB-83, WB-258, WB-230, WB-222, WB-258-1, WB-206, WB-358, WB-224, WB-1012, WB-1011 and WB-409 had high mean value as compared to population mean and thus, were well adapted to all the environments, whereas, rest all genotypes were having mean value less than population mean and thus, were poorly adapted to all the environments.

4.6.1.7 Pod yield plant⁻¹

Estimation of stability parameter for pod yield plant⁻¹ is presented in (Table-6.4). The mean value for pod yield plant⁻¹ ranged from 29.3 g (WB-255) to 113.1g (WB-1012) with mean ($\bar{X}$) of all the genotypes being 84.60g. The non-linear component (S_{di}^2) was non-significant for all the genotypes except WB-143, 158, 230, 257, 222, 258-1, 411, 370 and WB-1115 indicating that the stability for these genotypes would be precise. The linear regression (b_i) ranged from -0.4 (WB-258-1) to 3.2 (WB-257) and was found statistically non-significant (no deviation from unity) for all genotypes except WB-257 and WB-222. All the cultivars showing non-significant S_{di}^2 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 WB-38, WB-83, WB-143, WB-258, WB-230, WB-257, WB-222, WB-128, WB-461, WB-1011, WB-8 and WB-1012 had high mean value as compared to population 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.

4.6.1.8 100-seed weight

The mean values and stability parameters b_i and S_{di}^2 for 100 seed weight are presented in (Table-6.5). Mean values to assess the boldness of the variety in terms of 100 g grain weight revealed a range of 24.7 g (WB-230) to 61.1 g (WB-240), with a population mean of 34.0 g. the deviation from regression (S_{di}^2) was non-significant for all traits making it possible to prophesy the stability of almost all the genotypes precisely across the environments. The linear regression (b_i) ranged from -0.9 (WB-158) to 2.1 (WB-370) and was found statistically non-significant (no deviation from unity) for most of genotypes except WB-255 and WB-370. All the cultivars showing non-significant S_{di}^2 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 WB-38, WB-83, WB-158, WB-257, WB-128, WB-224, WB-240, WB-450, and WB-8 had high mean value as compared to population 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_{di}^2 value, the b_i values could safely presumed to be equal to unity and thus, could be assumed to be average in stability.

4.6.1.9 Seed yield plot⁻¹

Estimation of stability parameter for seed yield plant⁻¹ is presented in (Table-6.6). The mean value for seed yield plant⁻¹ ranged from 308 g (WB-255) to 1976.4 g (WB-83) with mean ($\bar{X}$) of all the genotypes being 1198.1g. The non-linear component (S_{di}^2) was non-significant for all the genotypes except WB-38, 258 and WB-83 indicating that the stability for these genotypes would be precise. The linear regression (b_i) ranged from -0.9 (WB-258-1) to 3 (WB-257) and was found statistically non-significant (no deviation from unity) for all genotypes (table 6.6) except WB-257 and WB-222. All the cultivars showing non-significant S_{di}^2 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 WB-38, WB-83, WB-258, WB-143, WB-257, WB-1137, WB-128, WB-461, WB-1011, WB-1012, 400, 450 and WB-8 had high mean value as compared to population 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.

Table-6.4: Stability parameters for pod length and pod yield/plant (g) in varieties of common bean evaluated across four random environments

Genotypes	Pod length			Pod yield/plant(g)		
	Mean ($\bar{X}$)	b_i	S^2d_i	Mean ($\bar{X}$)	b_i	S^2d_i
WB-38	10.9	1.0	0.04	87.3	0.6	0.8
WB-83	11.2	2.0	-0.05	89.7	0.5	0.5
WB-143	11.5	1.2	0.1	93.7	1.1	7.5
WB-184	12.2	1.8	-0.07	68.2	1.6	2.1
WB-158	10.0	1.0	0.9	81.6	0.8	5.2
WB-258	10.1	1.9	0.01	87.2	1.4	0.7
WB-230	11.8	1.5	0.4	86.1	0.8	8.4
WB-255	7.0	1.5	0.2	29.3	1.0	3.3
WB-257	13.4	-0.7	1.03	92.2	3.2	9.0
WB-222	10.3	1.8	0.2	95.5	2.2	5.9
WB-243	11.2	0.4	-0.06	41.8	0.4	0.08
WB-258-1	12.9	0.1	2.7	74.3	-0.4	50.6
WB-206	11.6	1.2	0.5	76.8	0.8	0.5
WB-261	9.3	1.02	0.7	58.9	0.6	9.6
WB-358	9.9	1.5	0.5	78.2	0.3	23.8
WB-128	10.1	2.05	0.2	92.0	1.3	44.2
WB-224	9.3	2.4	0.3	55.9	0.7	52.5
WB-240	7.1	-0.8	1.4	71.7	1.4	2.03
WB-1137	9.6	0.2	0.04	86.5	1.6	2.4
WB-461	10.4	0.5	0.04	112.1	1.9	20.5
WB-443	10.3	2.5	0.19	55.4	0.8	38.7
WB-409	10.3	0.4	-0.1	89.4	1.5	2.0
WB-411	11.8	-0.6	0.3	84.8	1.3	8.6
WB-1011	9.0	1.01	2.3	107.6	1.0	1.7
WB-1012	10.8	0.6	0.3	113.1	0.3	5.0
WB-370	9.9	1.5	0.05	81.8	0.7	3.6
WB-400	9.4	0.8	1.7	81.1	0.3	7.1
WB-450	9.7	1.1	0.5	94.3	-0.07	1.2
WB-370	10.7	1.0	0.04	74.1	1.4	7.07
WB-1115	12.2	-1.9	1.2	54.2	0.9	4.1
WB-8	10.5	1.9	0.05	108.7	0.7	1.6
Population mean		10.4			84.6	
SE(m)		0.4			4.3	
SE(b_i)		1.0			0.4	

Table-6.5: Stability parameters for seeds per pod and 100 seed weight (g) in varieties of common bean evaluated across four random environments

Genotypes	Seeds per pod			100 seed weight (g)		
	Mean ($\bar{X}$)	b_i	S^2d_i	Mean ($\bar{X}$)	b_i	S^2d_i
WB-38	4.9	1.5	-0.05	37.0	1.2	1.01
WB-83	4.8	-0.	1.1	39.1	2.0	3.5
WB-143	3.0	1.9	0.1	32.6	1.7	0.4
WB-184	4.5	0.8	0.06	35.8	1.3	0.4
WB-158	4.7	1.4	0.1	38.1	-0.9	0.8
WB-258	5.5	1.6	0.08	33.8	1.6	6.7
WB-230	4.9	2.3	0.2	24.7	0.8	3.9
WB-255	3.2	2.6	0.03	28.4	2.0	2.5
WB-257	3.6	0.7	0.6	40.9	0.5	0.2
WB-222	5.4	0.7	-0.06	33.1	0.8	0.3
WB-243	4.4	1.2	-0.06	29.8	1.7	0.5
WB-258-1	7.2	1.2	0.9	26.9	-0.3	2.3
WB-206	5.2	2.8	0.02	27.9	1.2	1.3
WB-261	4.9	0.3	0.2	33.6	1.1	-0.08
WB-358	5.6	-0.6	1.8	28.6	0.8	1.2
WB-128	4.5	1.1	0.3	40.7	0.3	7.7
WB-224	6.1	0.1	0.1	37.3	0.7	0.5
WB-240	3.9	1.4	0.04	61.1	-0.1	32.3
WB-1137	5.3	0.7	-0.01	34.2	1.1	1.2
WB-461	4.9	-0.1	0.2	28.1	1.5	1.1
WB-443	4.4	1.6	-0.06	28.4	0.5	1.6
WB-409	5.2	0.6	-0.05	30.8	1.5	-0.1
WB-411	4.3	0.8	-0.03	32.9	0.5	0.06
WB-1011	5.0	0.2	1.4	28.3	0.9	0.2
WB-1012	5.8	0.3	1.2	30.3	0.2	0.9
WB-370	4.8	0.02	0.2	36.3	1.0	0.1
WB-400	4.8	-2.1	1.03	34.6	1.3	0.3
WB-450	4.9	1.2	0.08	39.8	0.7	11.2
WB-370	3.4	0.4	-0.07	29.9	2.1	1.2
WB-1115	3.8	3.0	0.1	34.0	0.5	3.3
WB-8	4.6	2.4	0.04	45.8	0.6	2.2
Population mean		4.7			34	
SE(m)		0.3			1.0	
SE(b_i)		1.4			1.2	

Table-6.6: Stability parameters for seed yield per plot (g) in varieties of common bean evaluated across four random environments

Genotypes	Seeds yield per plot		
	Mean ($\bar{X}$)	b_i	$S^2 d_i$
WB-38	1811.5	0.8	7.5
WB-83	1976.4	0.6	8.0
WB-143	1345.0	1.0	4.0
WB-184	984.3	1.7	1.5
WB-158	1207.4	0.9	5.1
WB-258	2537.7	1.8	1.0
WB-230	705.8	0.7	0.4
WB-255	308.0	0.8	0.3
WB-257	1303.1	3.0	8.4
WB-222	2790.4	2.0	5.3
WB-243	545.8	0.6	6.8
WB-258-1	1009.0	-0.9	7.8
WB-206	975.0	0.5	-12.3
WB-261	823.6	0.7	6.6
WB-358	1083.8	-0.01	3.8
WB-128	1269.6	1.4	4.1
WB-224	750.4	0.5	6.3
WB-240	997.4	0.2	1.0
WB-1137	1204.9	2.0	4.8
WB-461	1537.5	1.8	6.4
WB-443	755.9	1.0	9.4
WB-409	1285.9	1.6	2.6
WB-411	1177.4	1.2	1.5
WB-1011	1544.3	1.2	2.37
WB-1012	1642.4	0.01	1.5
WB-370	1157.2	1.01	7.8
WB-400	1211.7	-0.3	5.1
WB-450	1392.9	0.02	1.9
WB-370	1036.7	1.8	1.8
WB-1115	781.7	1.1	2.4
WB-8	1538.0	0.9	-2.1
Population mean		4709.00	
SE(m)		21.30	
SE(b_i)		0.50	

4.7 Bush type of trials

4.7.1 Estimation of stability parameters and identification of stable genotypes (as per Eberhart and Russell's Model 1966) of bush type of genotypes

Estimation of stability parameters for different traits viz. morphological (days to 50% flowering, days to maturity, plant height) yield components (pods plant⁻¹, pod length, number of seeds pod⁻¹, 100-seed weight) and yield (pod yield plant⁻¹, seed yield plot⁻¹) across four random environments are presented in the Table-5. The stability parameters estimated were mean of the trait ($\bar{X}$), linear regression (b_i) mean square deviation from regression (S_{di}^2), where $\bar{X}$ provides a measure of the performance of a variety as compared to other entries, the b_i and S_{di}^2 values are the measure of the $G \times E$ interaction. The components S_{di}^2 measures predictability and the component b_i measure the stability. In general, if $G \times E$ is non-significant or where this $G \times E$ interaction is either linear or predominantly linear as compared to its non-linear component, the prediction of stability of a genotype over environments becomes more reliable. As per the Eberhart and Russel's model of stability, the component S_{di}^2 measures predictability and b_i the stability. Stability of a genotype can be predicted more precisely if $G \times E$ interaction and S_{di}^2 value are non-significant (table-7.1).

4.7.1.1 Days to 50% flowering.

Estimation of stability parameter for the number of days to 50% flowering is presented in Table-7.2. The mean value ranged from 40.1 (WB-22) to 55.5 (WB-490) and with a population mean ($\bar{X}$) of 47.1 days. The mean performance of all genotypes was highly significant for all traits. The regression coefficient (b_i) was non-significant for all genotypes except few which include WB-209, WB-1031, WB-479, WB-54 and WB-885 and it ranged from -4.5 to 2.5. Thus, all these genotypes were average in stability and either poorly or well adapted to environments. The estimation of mean square deviation from regression (S_{di}^2) was non-significant for all varieties except WB-479, WB-54, WB-489, WB-852, WB-

Table-7: Analysis of variance of Mother trial for Bush type of genotypes

Source of variation	d.f.	Mean sum of squares								
		Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of pods plant ⁻¹	Pod length (cm)	Pod yield plant ⁻¹ (g)	Seeds pod ⁻¹	Seed yield plot ⁻¹ (g)	100-seed weight (g)
Genotype	22	66.7**	75.8**	2032.3**	47.94	9.3**	2095.2**	3.6**	417361.1**	73.5**
Replication	2	11.9**	79.8**	40.4**	7.07	6.5**	177.0**	0.9**	17151.2**	11.9**
Error	176	16.7**	24.3**	330**	26.59	2.6**	306.8**	0.9**	74877.4**	34.3**

Table-7.1: Analysis of variance for stability of different traits in bush type genotypes across four environments

Source of variation	d.f.	Days to 50% flowering	Days to Maturity	Plant height	No. of pods ⁻¹ plant	Pod length	Pod yield/plant	Seeds/pod	100 seed weight (g)	Seed yield/plot
Replication With In Environments	8	0.2	0.9	0.4	0.4	0.2	3.1	0.1	0.2	441.4
Varieties	22	109.2**	122.6**	1661.7**	130.6**	12.1**	1642.5**	1.5**	151.6**	39611**
Environment + (Varieties × Environment)	69	4.0**	1.8**	7.5	21.8**	0.7*	928.2*	0.6	37.1*	22399*
Environments	3	11.7**	16.3**	7.4**	37.9*	8.2**	2363.9	0.8*	8.7**	34482**
Varieties × Environment	66	3.6**	1.2**	7.5*	21.0**	0.7*	862.9**	0.6*	38.4**	21850**
Environment (Linear)	1	35.6**	49.1**	22.4	113.9**	24.7**	7091.9**	2.5*	26.3	10348*
Varieties × Environment (Linear)	22	7.4***	2.4**	5.8	43.7**	0.4**	810.2*	0.9*	73.4**	24864*
Pooled Deviation (Non Linear)	46	1.6**	0.6**	8.0*	9.3**	0.4**	850.6**	0.4**	20.0**	19458**
Pooled Error	176	0.4	0.4	0.5	0.2	0.1	4.5	0.08	0.2	432.3
Total	91	29.4	31.0	407.4	48.1	3.5	1100.9	0.8	64.8	205606

* Significant at p=0.05; ** Significant at p=0.01

209 and WB-191 making it possible to predict precisely the stability of most of the genotypes regarding the trait across locations. All the cultivars showing non-significant deviation from regression (S_{di}^2) and regression coefficient (b_i) were average in stability and poorly or well adapted to the environments.

4.7.1.2 Days to maturity

The stability parameters b_i and S_{di}^2 along with the mean values for days to maturity are presented in Table-7.2. Days taken to maturity divulged a wide magnitude of variability for the mean performance of the genotypes across the location, which ranged from 82.2 (WB-569) to 97 (WB-147) with a population mean of 88.3 days. The deviation from regression (S_{di}^2) was non-significant for all varieties except WB-22, 209, 489, 487 and WB-852 making it possible to predict precisely the stability of most of the genotypes regarding their maturity across locations. The regression coefficient (b_i) ranged from -1.0 to 4.6. Maximum genotypes revealed significant deviation of regression coefficient <1.0 except WB-22, WB-209, WB-479, WB-489, WB-487, and WB-852. The genotype WB-185, WB-195, WB-634, WB-462, WB-490, WB-1031, WB-569, WB-330, WB-479, WB-489, WB-487, WB-852, WB-966, and WB-885 exhibited earliness as compared to population mean and had regression coefficient significantly <1.0 . These genotypes revealed above average response to stability and is expected to mature earlier even under unfavourable environment. The genotypes WB-22, WB-147, WB-209, WB-223, WB-249, WB-191, WB-192 and WB-54 revealed significantly higher maturity than population mean and their corresponding regression coefficients were almost also significantly >1.0 , revealing all these genotypes exhibited, below average response to stability and could mature slightly late under favourable conditions.

4.7.1.3 Plant height

The stability parameters b_i and S_{di}^2 along with the mean values for plant height are presented in (Table-7.3) revealed that the tallest genotype was WB-885 (96.6 cm) and shortest WB-22 (32 cm), with the mean plant height ($\bar{X}$) of all

the cultivars being 65.4 cm. The difference among the cultivars for this trait was significant. The estimation of mean square deviation from the regression (S_{di}^2) was non-significant for all genotypes except WB-22, WB-192, WB-462, WB-490, WB-330, WB-479, WB-489 and WB-885 making it easy to predict stability of this trait over the environments for the genotypes showing non-significant S_{di}^2 . The linear regression value (b_i) ranged from -1.5 to 4.3 and these values were non-significant (no deviation from unity) for many genotypes except WB-54, WB-487, WB-852, WB-192, WB-462, WB-330 and WB-249. All the genotypes showing non-significant S_{di}^2 and b_i were average in stability and poorly or well adapted to the environments depending upon their genetic background.

4.7.1.4 Number of pods plant⁻¹

The mean values and stability parameters b_i and S_{di}^2 for number of pods plant⁻¹ are presented in (Table-7.3). The genotype WB-634 showed highest mean value (29.6) while WB-479 showed the lowest mean value (8.7) over four random environments with the mean value ($\bar{X}$) of all the genotypes being 15.8. The estimation of mean square deviation from the regression (S_{di}^2) 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 -3.4 (WB-223) to 3.9 (WB-22) and these values were non-significant (no deviation from unity) for all genotypes. All the cultivars showing non-significant S_{di}^2 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.

4.7.1.5 Pod length

The pod length of the genotypes ranged from 6.2 cm (WB-192) to 13.5 cm (Shalimar Rajmash-1) across the locations with population mean of 10.3 cm is presented in (Table-7.4). The magnitude of variability for this trait was broad. The

estimation of mean square deviation from the regression (S_{di}^2) 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 -0.07 to 2.4 and these values were non-significant (no deviation from unity) for all genotypes except WB-209, WB-192, WB-1031 and WB-885. All the cultivars showing non-significant S_{di}^2 and b_i were average in stability and poorly or well adapted to the environments. The genotypes WB-147, 209, 185, 249, 490, 1031, Shalimar Rajmash-1, 487 and 966 have above average mean performance and therefore are better adapted to all the environments.

4.7.1.6 Pod yield plant⁻¹

Estimation of stability parameter for pod yield plant⁻¹ is presented in (Table-7.4). The mean value for pod yield plant⁻¹ ranged from 40 g (WB-191) to 135.8g (WB-634) with mean ($\bar{X}$) of all the genotypes being 80.9g. The non-linear component (S_{di}^2) was non-significant for all the genotypes except WB-22, 195, 249, 191, 192, 490, 1031, 569, 330, 54, 479, 489 and WB-487 indicating that the stability for these genotypes would be precise. The linear regression (b_i) ranged from -0.6 (WB-54) to 4.3 (WB-249) and was found statistically non-significant (no deviation from unity) for all genotypes except WB-249, 462, 330, 192 and WB-479. All the cultivars showing non-significant S_{di}^2 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 WB-147, WB-195, WB-185, WB-249, WB-634, WB-262, WB-487, WB-966, WB-885 and Shalimar Rajmash-1 had high mean value as compared to population 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.

Stability parameters for different traits in Bush type varieties of common bean evaluated across four random environments

Table-7.2: Stability parameters for days to 50 % flowering and days taken to maturity in varieties of common bean evaluated across four random environments

Genotypes	Days to 50 % flowering			Days taken to maturity		
	Mean ($\bar{X}$)	b_i	S^2d_i	Mean ($\bar{X}$)	b_i	S^2d_i
WB-22	40.1	-1.6	0.5	94.3	2.1	-0.3
WB-147	45.0	1.2	0.2	97.0	1.7	0.8
WB-195	46.8	1.3	0.3	95.5	-1.0	0.02
WB-185	42.3	-3.0	0.7	93.0	0.7	-0.4
WB-209	42.7	2.3	-0.2	89.4	2.9	0.1
WB-223	42.9	1.9	-0.7	94.1	1.4	-0.1
WB-249	44.5	1.6	-0.1	93.0	1.6	0.1
WB-191	43.2	0.2	1.8	96.7	0.2	-0.1
WB-192	44.0	1.0	3.5	96.8	0.6	-0.3
WB-634	46.3	0.3	1.0	84.1	-0.06	0.04
WB-462	41.9	1.8	2.2	84.0	1.3	-0.1
WB-490	55.5	-2.9	1.1	86.9	1.8	0.4
WB-1031	51.9	2.0	-0.2	83.5	0.9	-0.4
WB-569	55.0	1.4	1.7	82.0	-0.2	0.9
WB-330	44.0	-4.5	1.5	82.9	0.09	-0.4
SR-1	46.8	1.4	0.7	86.1	0.06	0.3
WB-479	52.6	2.5	2.8	83.4	2.2	0.2
WB-54	42	2.0	2.6	91.6	1.6	-0.2
WB-489	45.0	1.9	2.4	82.4	4.6	-0.03
WB-487	51.8	1.4	-0.2	82.5	2.4	-0.1
WB-852	53.4	1.4	2.9	85.2	2.9	3.5
WB-966	47.1	1.4	0.8	83.1	0.6	-0.3
WB-885	42.5	2.5	-0.06	84.6	1.4	1.02
Population mean		47.1		83.3		
SE(m)		0.7		0.4		
SE(b_i)		1.0		0.5		

Table-7.3: Stability parameters for plant height (cm) and number of pods plant⁻¹ in varieties of common bean evaluated across four random environments

Genotypes	Plant height (cm)			No. of pods per plant		
	Mean ($\bar{X}$)	b_i	S^2d_i	Mean ($\bar{X}$)	b_i	S^2d_i
WB-22	32.0	-1.5	9.7	17.6	3.9	6.3
WB-147	45.8	-3.5	11.6	21.2	0.6	-0.07
WB-195	55.9	1.2	0.2	25.4	1.0	0.03
WB-185	53.7	-0.8	0.01	14.7	-3.4	6.0
WB-209	37.4	-1.7	11.8	12.7	3.7	4.2
WB-223	45.1	1.7	0.5	28.8	0.6	0.5
WB-249	55.5	1.8	-0.3	13.5	1.3	0.4
WB-191	81.1	1.4	4.7	9.0	0.6	4.9
WB-192	37.5	-3.0	3.9	12.4	1.4	-0.01
WB-634	83.3	7.8	6.5	29.6	0.6	0.7
WB-462	76	2.2	3.1	11.8	-2.2	12.1
WB-490	88.4	3.1	8.8	12.5	1.3	0.3
WB-1031	74.5	1.4	-0.02	15.9	2.1	1.1
WB-569	69.3	3.4	-0.3	12.1	-1.4	7.3
WB-330	42.4	1.5	2.1	14.4	1.4	3.7
SR-1	67.1	1.0	-0.04	17.8	1.0	0.2
WB-479	62.2	0.8	1.6	8.7	-3.4	15.0
WB-54	45.6	3.0	0.3	11.7	-1.1	4.2
WB-489	94.1	-1.5	4.7	13.7	-1.0	5.6
WB-487	75.2	2.5	0.8	20.3	2.0	3.1
WB-852	84.7	2.4	-0.1	11.0	1.3	0.1
WB-966	93	1.2	0.9	16.0	-0.8	0.4
WB-885	96.6	0.7	1.5	16.3	1.9	0.4
Population mean		65.4			15.8	
SE(m)		1.6			1.7	
SE(b_i)		2.8			1.3	

Table-7.4: Stability parameters for pod length and pod yield/ plant (g) in varieties of common bean evaluated across four random environments

Genotypes	Pod length (cm)			Pod yield (g)		
	Mean ($\bar{X}$)	b_i	S^2d_i	Mean ($\bar{X}$)	b_i	S^2d_i
WB-22	9.5	0.3	0.2	80.6	1.5	1.3
WB-147	11.5	1.3	0.04	84.5	0.9	0.3
WB-195	9.6	0.7	-0.1	87.3	1.1	0.9
WB-185	10.1	1.1	1.4	84.4	1.8	4.4
WB-209	12.9	1.5	-0.1	66.5	0.8	0.05
WB-223	13.3	-0.07	0.7	126.7	-0.4	0.6
WB-249	12.1	0.7	-0.1	86.4	4.3	2.2
WB-191	10.4	0.9	0.7	40.0	1.9	1.4
WB-192	6.2	2.4	-0.1	55.2	3.9	2.1
WB-634	8.1	0.8	-0.1	135.8	0.01	0.2
WB-462	9.2	1.2	2.1	91.1	5.7	4.6
WB-490	12.6	0.9	-0.04	63.3	1.2	2.01
WB-1031	11.0	1.3	0.9	68.5	0.1	3.4
WB-569	10.3	1.2	-0.1	70.8	1.9	3.2
WB-330	9.5	1.1	3.7	73.2	3.5	2.7
SR-1	13.5	1.0	-0.1	96.2	-0.3	0.5
WB-479	8.6	0.9	-0.05	74.7	2.05	2.5
WB-54	9.4	0.4	-0.1	70.0	-0.6	3.7
WB-489	9.8	1.5	-0.1	81.1	0.5	2.5
WB-487	11.1	1.2	-0.04	96.4	0.9	2.5
WB-852	10.3	1.5	0.1	71.6	1.5	0.7
WB-966	10.4	0.5	-0.01	89.0	-0.3	0.8
WB-885	9.4	1.5	0.04	85.7	1.1	0.8
Population mean		10.3			80.9	
SE(m)		0.3			16.8	
SE(b_i)		0.6			1.6	

4.7.1.7 Seeds pod⁻¹

The stability parameters b_i and S_{di}^2 along with the mean values for seeds panicle⁻¹ are presented in (Table-7.5). The mean value for number of seeds pod⁻¹ ranged from 3.4 (WB-192) to 5.9 (WB-490) with mean ($\bar{X}$) of all the genotypes being 4.8. The non-linear component S_{di}^2 was non-significant for all the genotypes except WB-192, 462, 1031, 54, 852 and WB-885 indicating that the stability for these genotypes would be precise. The linear regression (b_i) ranged from -5 (WB-490) to 3.3 (WB-54 and 852) and was found statistically non-significant except genotype WB-249, 191, 192, 462, 1031, 54, 852 and 885. 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_{di}^2 values were, by and large, average in stability. However, judging from the mean performance it was observed that the genotypes WB-22, WB-185, WB-249, WB-634, WB-490, WB-1031, WB-569, WB-330, WB-479, WB-487, WB-966 and Shalimar Rajmash-1 had high mean value as compared to population 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.

4.7.1.8 100-seed weight

The mean values and stability parameters b_i and S_{di}^2 for 100 seed weight are presented in (Table-7.5). Mean values to assess the boldness of the variety in terms of 100 g grain weight revealed a range of 27.8 g (WB-1031) to 50.6 g (WB-54), with a population mean of 34.4 g. the deviation from regression (S_{di}^2) was non-significant for all traits making it possible to prophesy the stability of almost all the genotypes precisely across the environments. The linear regression (b_i) ranged from -18.7 (WB-54) to 10 (WB-249) and was found statistically non-significant (no deviation from unity) for most of genotypes except WB-185,490, 569, 330 and WB-479. All the cultivars showing non-significant S_{di}^2 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 WB-22, WB-223, WB-209, WB-185, WB-192, WB-634, WB-489, Shalimar Rajmash-1 had high mean value as compared to population 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_{di}^2 value, the b_i values could safely presumed to be equal to unity and thus, could be assumed to be average in stability.

4.7.1.9 Seed yield plot⁻¹

Estimation of stability parameter for seed yield plant⁻¹ is presented in (Table-7.6). The mean value for seed yield plant⁻¹ ranged from 501.8 g (WB-191) to 2540.1 g (WB-185) with mean ($\bar{X}$) of all the genotypes being 1142.8g. The non-linear component S_{di}^2 was non-significant for all the genotypes except WB-147, 223, 192, 462, 490, 1031, 569 and WB-479 indicating that the stability for these genotypes would be precise. The linear regression (b_i) ranged from -1.3 (WB-54) to 6.3 (WB-249) and was found statistically non-significant (no deviation from unity) for all genotypes except WB-22, 249, 462, 569, 479 and WB-852. All the cultivars showing non-significant S_{di}^2 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 WB-147, WB-195, WB-223, WB-185, WB-249, WB-634, WB-462, WB-489, Shalimar Rajmash-1, WB-489, WB-966 and WB-885 had high mean value as compared to population 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.

Table-7.5: Stability parameters for seeds per pod and 100 seed weight (g) in varieties of common bean evaluated across four random environments

Genotypes	Seeds per pod			100 seed weight (g)		
	Mean ($\bar{X}$)	b_i	S^2d_i	Mean ($\bar{X}$)	b_i	S^2d_i
WB-22	4.7	-0.4	-0.01	42.8	11.4	1.3
WB-147	4.0	0.1	0.1	31.1	1.6	51.1
WB-195	4.0	0.2	0.5	30.8	-1.3	0.5
WB-185	4.0	-4.1	0.3	41.0	-1.4	7.8
WB-209	4.6	1.6	-0.03	38.2	1.5	0.07
WB-223	5.4	0.8	0.03	36.3	2.6	0.8
WB-249	4.9	2.6	0.1	28.5	10.0	4.1
WB-191	4.1	6.1	0.6	28.4	0.7	7.2
WB-192	3.4	3.0	2.1	42.9	-15.3	0.4
WB-634	5.1	-0.4	0.2	38.4	0.6	0.5
WB-462	4.5	2.6	0.2	29.8	2.2	3.9
WB-490	5.9	-5.0	2.4	28.3	2.5	2.9
WB-1031	5.2	3.1	0.1	27.8	-1.2	9.8
WB-569	5.1	1.1	-0.04	31.3	2.4	3.4
WB-330	5.7	-1.1	-0.02	31.1	5.0	1.6
SR-1	4.7	-1.8	0.4	39.2	-7.7	2.8
WB-479	5.6	-1.7	0.9	36.8	2.4	3.9
WB-54	4.3	3.3	0.7	50.6	-18.7	1.4
WB-489	4.8	-1.3	0.5	40.3	0.8	0.2
WB-487	5.0	1.1	-0.07	29.6	1.3	0.6
WB-852	4.6	3.3	0.03	29.9	0.8	10.8
WB-966	5.1	0.2	0.2	30.2	0.5	0.3
WB-885	4.7	2.9	0.01	31.3	-1.8	5.3
Population mean		4.8			34.4	
SE(m)		0.3			2.5	
SE(b_i)		2.0			4.1	

Table-7.6: Stability parameters for seed yield per plot (g) in varieties of common bean evaluated across four random environments

Genotypes	Seed yield per pod		
	Mean ($\bar{X}$)	b_i	S^2d_i
WB-22	1135.8	2.2	1.5
WB-147	1214.8	-0.2	3.7
WB-195	1371.7	0.3	0.5
WB-185	1299.6	0.8	2.2
WB-209	968.2	1.0	0.6
WB-223	2540.1	-0.8	0.2
WB-249	1243.5	6.3	1.1
WB-191	501.8	1.9	1.0
WB-192	796.0	-0.5	2.2
WB-634	2011.2	-0.8	0.1
WB-462	1314.5	8.1	5.9
WB-490	843.4	-1.05	7.2
WB-1031	900.2	-0.2	3.9
WB-569	952.1	2.5	3.6
WB-330	1053.3	-0.8	1.8
WB-487	1227.8	-0.8	1.6
WB-479	1010.7	2.3	8.9
WB-54	964.4	-1.3	1.3
WB-489	1549.8	0.1	0.2
SR-1	1337.2	1.3	0.7
WB-852	975.5	2.9	2.6
WB-966	1138.5	0.8	0.1
WB-885	1215.1	1.4	0.3
Population mean		1142.8	
SE(m)		64.7	
SE(b_i)		2.1	

4.8 Baby trial evaluation

The genotypes selected from the mother trial were evaluated through baby trials. Out of the total 54 genotypes of both pole and bush type, only six genotypes namely WB-185, WB-83, WB-966, WB-258, WB-195 and Shalimar Rajmash-1 were selected for baby trial evaluation in the next year based on preferential index values of mother trials. The baby trials were laid in three districts namely Baramulla, Kupwara and Bandipora of Kashmir valley. The baby trials were laid both in the area/ villages where the mother trials were laid and other villages also. In total there were twenty number of baby trials across three districts of north Kashmir. The baby trials were not laid at the research stations but exclusively at the farmers' field. The area under baby trial was more than that of the mother trial. However in case of private sector, strip of crop variety is laid which proves more economical than the research baby trial and gives same result.

The area under baby trial was more than that of the mother trial. Generally one variety is evaluated in baby trial against the farmers' check. We can have two or more varieties to be checked in the baby trial system against the farmers' check. Generally the variety given to a farmer is considered as a treatment with the farmers' as different replicates. The evaluation of the genotypes in case of baby trials is simply carried out on the basis of more, same or less against the established farmers' check. The comparison of the varieties with the local check and between the varieties was done on the basis of focused group discussions (FGD). The analysis of baby trials was simply carried out, by means of changing the data into percentages individually of the parameter same, more and less and calculating the general mean of the percentages individually. The standard deviation was also calculated from the data for interpretation.

4.8.1 Comparison of the bean genotypes at farmers' field

The farmers' perceptions about the six *rajmash* varieties were assessed through the focused group discussions. The six varieties (WB-185, WB-83, WB-

195, WB-966, WB-258, and Shalimar Rajmash-1) were compared with the farmers' local check for various yield and yield attributing traits viz., days to flowering, days to maturity, number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot. These varieties vary considerably in different traits with each other and with the local check.

Variety WB-185 when compared with the local check shows days to 50% flowering is almost same as compared to check as 90% of farmers vote in this favour. 94.3% of farmers' vote that, days to maturity is same as compared to check while only 5.6% vote that it needs more days for maturity. However the farmers' reflect that the variety is having more number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check viz., 93.5, 94.2, 95.7 and 95.9% of farmers respond in favour respectively. So from the data and table it reflects that the variety is more desirable than the check in all the yield attributing traits (Table 8.1). The variety is red in colour with kidney shape and bush type of plant structure makes it more desirable and fit to the farming community.

Variety Shalimar Rajmash-1 when compared with the local check shows days to 50% flowering is almost same as compared to check as 83.7% of farmers vote in this favour and only 16.82% vote as the variety having more days to 50% flowering than the check. 90.5% of farmers' vote that, days to maturity is more as compared to check while only 9.5% vote that it needs same days for maturity when compared with the check. However, the farmers' preferences and voting reflect that the variety is having almost same number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check viz., 94.4, 90.45, 88.09 and 90.9% respectively. So from the data and table it reflects that the variety is almost same as compared to the local check and is not desirable in all the yield attributing traits (Table 8.1). The variety is not favoured also because of more damage due to susceptibility to bean common mosaic virus. The variety is having selective advantage over the farmers check as the variety is red in colour

with kidney shape (preferred traits) assuming bush type of plant architecture.

Variety WB-966 when compared with the local check shows that the traits vary considerably among themselves between more, same and less. 52.28% of farmers' reflect that days to 50% flowering is almost less as compared to check and 44.25 and 20.1% of famers vote that it is having more and same days to 50% flowering as compared to check respectively. 87.1% of farmers' vote that, days to maturity is more as compared to check while only 15.1 and 15% vote that it needs same and less number of days for maturity than check. However the farmers' reflect that the variety is having almost same number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check viz., 93.5, 83.27, 91.35 and 86.53% respectively. So from the data and table it reflects that the variety is not desirable than the check as such in all the yield attributing traits, but can be grown as few yield attributing traits are more tilted towards the variety compared to the check (Table 8.1). The variety is also having selective advantage over the farmers check as the variety is red in colour with kidney shape (preferred traits) assuming bush type of plant architecture.

Table-8.2 reflects that Variety WB-83 when compared with the local check shows days to 50% flowering is less as compared to check as 93.2% of famers vote in this favour. 96.1% of farmers' vote that, days to maturity is less as compared to check while only 8.6% vote that it needs same days for maturity. However the farmers' reflect that the variety is having more number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check viz., 94.4, 92.5, 96.2 and 96.0% of farmers respond in this favour respectively. So from the data and table it reflects that the variety is more desirable than the check in all the yield attributing traits (Table 8.2). So from the Table it reflects that, when we compare it with WB-185 and others, the variety is more desirable among all the traits than other varieties and the farmers' check. It is pole type of *rajmash* with purple colour of seeds and Cuboidal in shape collected locally from the valley. It is mostly grown with maize and is highly adapted with it to give higher yields.

Table-8: List of genotypes selected from the Mother trials with certain characteristics

Trait/genotype	WB-185	WB-83	WB-195	WB-966	WB-258	SR-1
Colour	Red	Purple	Chocolate	Red	Red	Red
Shape	Kidney	Cuboidal	Kidney	Kidney	Cuboidal	Kidney
Source	Ciat (Columbia)	Local	Local	Ciat (Columbia)	Kishtwar	SKUAST- K (crimson red × local red)
Plant type	Bush	Pole	Bush	Bush	Pole	Bush

Table-8.1: Statistical analysis of farmers' perception (%) of common bean varieties in comparison to local land race through baby trial evaluation system

Trait	WB-185 vs. Farmers Check			SR-1 vs. Farmers Check			WB-966 vs. Farmers Check		
	Farmers preferences			Farmers preferences			Farmers preferences		
	More	Same	Less	More	Same	Less	More	Same	Less
Days to flowering	9.22±0.5	90±2.18	0±0	16.82±0.7	83.17±1.1	0±0	44.25±1.4	20.1±0.6	52.28±1.9
Days to maturity	5.6±0.4	94.3±0.8	0±0	90.5±1.1	9.5±0.5	0±0	87.1±1.04	15.1±0.4	15±0.4
No of pods/plant	93.5±0.7	6.47±0.5	0±0	5.59±0.4	94.4±0.7	0±0	6.4±0.5	93.52±0.7	0±0
Pod yield/plant	94.2±0.8	5.76±0.48	0±0	9.54±0.5	90.45±1.08	0±0	16.7±0.4	83.27±0.9	0±0
Seeds/pod	95.7±0.93	4.213±0.44	0±0	8.02±0.4	88.09±0.7	14.86±0.	8.6±0.5	91.35±0.7	0±0

Table-8.2: Statistical analysis of farmers' perception (%) of common bean varieties in comparison to local land race through baby trial evaluation system

Trait	WB-185 vs. Farmers Check			SR-1 vs. Farmers Check			WB-966 vs. Farmers Check		
	Farmers preferences			Farmers preferences			Farmers preferences		
	More	Same	Less	More	Same	Less	More	Same	Less
Days to flowering	-	8.99±0.4	93.2±1.02	18.98±0.5	79.82±1.1	19.58±0.5	15.41±0.5	88.44±1.3	0±0
Days to maturity	-	8.6±0.4	96.1±0.8	16.5±0.3	94.02±0.9	15.2±0.2	6.4±0.5	94.02±0.9	0±0
No of pods/plant	94.4±0.7	5.59±0.4	0±0	14.58±0.3	86.657±0.8	18.95±0.5	91.48±1.09	8.59±0.5	0±0
Pod yield/plant	92.57±0.7	7.429±0.5	0±0	17.90±0.5	87.35±0.8	18.65±0.3	98.45±0.9	10.31±0.3	0±0
Seeds/pod	96.20±1.05	5.063±0.4	0±0	14.75±0.4	93.76±0.8	16.98±0.3	95.90±0.8	11.68±0.4	0±0

Variety WB-258 when compared with the local check shows that the vote in favour of different traits varies considerably among themselves between more, same and less. 79.82% of farmers' reflect that days to 50% flowering is almost same as compared to check and 18.98 and 19.58% of famers vote that it is having more and less days to 50% flowering as compared to check respectively. 94.02% of farmers' vote that, days to maturity is same as compared to check while only 16.5 and 15.2% vote that it needs more and less number of days for maturity than check. However the farmers' in general reflect that the variety is having almost same number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check viz., 86.65, 87.35, 93.76 and 94.02% of farmers response were in its favour regarding the traits respectively. So from the data and table it reflects that the percentage response of farmers' regarding the variety vary considerably among different traits, hence the variety is not as such desirable than the check in all the yield attributing traits, but can be grown as few yield attributing traits are more tilted towards the variety compared to the check (Table 8.2). It is pole type collected locally from the Kishtwar area of the Jammu having red colour with Cuboidal shape being the traits preferred by the farmers.

Table-8.2 reflects that Variety WB-195 when compared with the local check shows days to 50% flowering is same as compared to check as 88.4% of famers vote in this favour against 15.41% which respond that variety is having more days to 50% flowering than check. 94.02% of farmers' vote that, days to maturity is same as compared to check while only 6.4% vote that it needs more days for maturity than check. However the farmers' reflect that the variety is having more number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check viz., 91.48, 98.45, 95.90 and 96.02% respectively. So from the data and table it reflects that the variety is more desirable than the check in all the yield attributing traits (Table 8.2). It is bush type of *rajmash* collected locally having chocolate colour with kidney shape being the traits preferred by the farmers.

Chapter – 5

DISCUSSION

The present investigation entitled “Participatory Varietal Selection in Rajmash (*Phaseolus vulgaris* L.) through Mother-Baby trial evaluation system in Baramulla, Bandipora and Kupwara districts of Kashmir”, was undertaken to generate baseline information about the farmers production constraints, varietal preferences and livelihood opportunities associated with *rajmash* in three districts of Kashmir valley. Under the university’s renewed focus on adding relevance to varietal developmental process, *rajmash* was identified as one of the target crops in view of its niche status as well as continuing dismal performance of pulses due to a host of socio-economic, biological farming system as well as production constraints. The present study aimed at identification of farmer and non-farmer attributes of *rajmash* based farming system as well as farmers’ varietal preferences that meet their aspirations. The results of the study are discussed under appropriate headings in light of the available literature. Fifty four (54) genotypes of both bush and pole type *rajmash* including farmer’s variety (as check) were evaluated through mother trial evaluation system in three districts of Kashmir to identify the most appropriate genotypes on the basis of preferences of the farmers’ and to find the varietal specification to be bred in future in consultation with farmers’. Out of these 54 genotypes 6 were selected by the farmers’ for baby trial evaluation. There were six Mother trials laid out in the farmers’ field including one Grandmother trial laid at Regional Research Station (RRS), Wadura, Sopore. The experiment was laid in Randomized Complete Block Design (RCBD) with three replications. Further stability of the genotypes was evaluated by following Eberhart and Russell model (1966). Before laying out of the trials, Participatory Rural Appraisal (PRA) was conducted extensively in the 32 locations across three districts. The experimental results on these aspects in the light of available literature are discussed below under following headings.

5.1 General landscape of bean farmers in the study area

The *rajmash* trials were laid at three districts, viz. Kupwara, Baramulla and Bandipora of North Kashmir. The basic profile of these districts is presented in Annexure-IV. Among these districts the area under pulses is maximum in Baramulla followed by Bandipora and Kupwara, which is probably due to the higher emphasis on maize and *rajmash* mixed cropping due to topographical advantage. The highest cropped area is in Baramulla followed by Kupwara and Bandipora.

5.2 Participatory rural appraisal

The first and the foremost step in initiating a PPB programme is to get a better insight of advantages and disadvantages that farmers of a particular area have owing to factors that are related to socioeconomic status, farming system characteristics and livelihood opportunities. Some of these factors have been reported to have significant effect on net productivity of farming systems but plant breeders have invariably failed to appreciate such factors from outside. Therefore, it is imperative that while we design a PPB programme, we are aware of the diverse attributes of farmers' and their farming system. 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). Participatory Rural Appraisal (PRA) based on questionnaire, conducted to know about the production constraints, varietal attributes and livelihood opportunities associated with *rajmash*. The basic components of PRA understand community and demands, documentation of local practices and documentation of local materials. The response of farmers' was overwhelming and encouraging in terms of the interest and enthusiasm for providing information, for generating a basic dataset for underlining the future priorities in *rajmash* breeding programmes, aimed at developing and delivering farmer preferred varieties in niche areas that possess

adaptability and resilience under the prevailing farming systems in the target areas.

In the process of PRA, information is obtained on the biotic and abiotic stresses most commonly encountered in the target areas and currently adapted varieties and their importance. However, without some prior knowledge of the target area, involves the risk of wasting resources and losing credibility with farmers' by testing highly unsuitable varieties (Joshi *et al.*, 2002). A successful PRA provides the information needed to specify the characteristic in a new variety regarding its physical environment and the existing varietal diversity. Sumberg and Reece (2004) argue that *de facto* Participatory Plant Breeding (PPB) program do not lead to a new product development orientation. For a breeding program, well applied PRA techniques or customer profiling results is better client orientation and makes possible efficient goal setting or product design (Sumberg and Reece, 2004). Successful PRA provides everything that could be included in the full design specification of a new crop variety. Witcombe *et al.* (2005) while high lighten the importance of Participatory Rural Appraisal (PRA) in plant breeding, and focuses on the issue relating to the particular target crop. In the present study PRA was conducted in the form of HHS and focus group discussions in 32 locations in three identified districts. A structured questionnaire was designed and probing technique used to derive as much relevant information about constraints and preferences of *rajmash* farmers that can be used to reorient the breeding programme.

5.2.1 Rajmash in farming system

The results revealed that *rajmash* was the most preferred summer season pulse crop ahead of cowpea and moong. This is invariably due to inherent cultural and farming system attributes of this crop including ability to fit in both sole and mixed cropping, short duration, building soil fertility, ability to sustain yields under limited water and input support and ability to fetch substantial revenue in short duration in view of rising prices of pulses.

5.2.2 Understanding production constraints of bean farmers in study areas

In the present investigation the PRA was conducted to get the background information, identify major production constraints and to determine the farmers' perception about varietal specification of *rajmash* under high altitude low production potential system of Kashmir valley. In the Participatory Rural Appraisal technique, the proforma was composed of few questions relating to the bean production constraints. Farmers were asked questions about the major factors limiting productivity of *rajmash* including farming system constraints, management constraints as well as biotic and abiotic factors. Significantly, the production constraints identified by farmers in all the locations did not include soil fertility possibly due to inherent capacity of beans to build soil fertility due to nitrogen fixing ability. The interaction with the farmers' through a structured questionnaire revealed that non availability of high yielding varieties was a major limiting factor for low yield. Farmers were having very limited choice regarding varietal diversity and market class suitability. Majority of the farmers in the three districts revealed that lack of high yielding varieties adapted to diverse varieties was a major factor for low yield. The unavailability of good source of seed is major concern as the unavailability of quality seed leads to continuous use of farmers saved seed by compulsion that has been a major factor for dismal seed replacement rate in pulses, in J&K state in general and Kashmir valley in particular.

Adamo (2001) and Wangui (2002) also highlighted that the lack of high yielding varieties was a major production constraint in Ethiopia. Rubyogo *et al.* (2012) also highlighted in Ethiopia and reported that inefficient seed delivery system is one of the main causes of low yield. Asfaw *et al.* (2013) in his study highlighted that the farmers' variety and seed management practices such as plant type selection, seed saving, and exchange practices, and their associated knowledge in southern Ethiopia, also provide a sort of barrier in the production of bean.

The biotic factor also provides a major threat to the production of *rajmash*. Among major production constraints low yielding varieties was identified a significant factor in limiting *rajmash* production followed by disease particularly BCMV. The diseases were a major biotic constraint limiting the crop yield. Majority of the farmers in the three districts revealed that the landrace/genotypes currently under cultivation were susceptible to different diseases especially BCMV/Anthracnose/Common rust and other various unrecognized diseases and insects especially pod borers and aphids as the biotic constraints limiting the production of *rajmash* yields. BCMV was a major disease limiting yields especially if it strikes the crop at early vegetative stage. Since the disease is mainly seed borne, the disease occurs every year with varied degrees of intensity, so due to the continued use of own saved seed of varieties, the disease occurs at a rapid speed.

Njoki (2013) while surveying in Kiambu county in Kenya using a semi-structured questionnaire, interviews, and focus group discussions, also found that farmers' cultivate *rajmash* during the short and long rain seasons. However, they experience better yields in the short rains due to reduced disease incidence. The majority of the farmers' (71%) intercrop *rajmash* and this ensures maximum utilization of space. A high percentage (70%) of the farmers' utilize their retained seed for production. The farmers' identified ALS as one of the most important constraints to production. The only preventive measure they undertake to control the disease is weeding. The farmers' reported that they preferred improved varieties that were resistant to ALS.

Among abiotic factor drought was identified to be a major factor (73.10%) for low yields in the *rajmash*. The drought comes at early season, or intermittent or as terminal drought severely affecting crop performance and consequent reduction in yield. Early season drought leads to poor germination and poor crop stands while as intermittent drought leads to flower abscission. Terminal drought usually leads to poor pod and seed set as well as seed cracking reducing the

market value. Drought also increased the seed cost as farmers use higher seed rates in anticipation of drought.

The crop is generally grown as a rainfed crop with the major threat of biotic and abiotic stresses. The farmers' prefer to go for the early harvest of the *rajmash* varieties to avoid the terminal drought conditions. The farmers' generally are having their own seed as source of seed, due to the reason of compulsion. However almost all farmers' were growing *rajmash* as a mixed crop with maize and potato without any proper row or intercrop arrangement which was due to the farmers' instinct of making maximum use of available land resources in view of the displacement of large areas under field crops to horticulture sector on account of greater profitability.

Asfaw *et al.* (2013) also reported that most of the bean farmers practised mixed cropping and grew varietal mixtures as is present in Kashmir valley also. Generally in hilly areas pole type or indeterminate varieties are cropped with the maize and in plain areas bush type or determinate type of *rajmash* are grown as a mixed crop with the potato/ vegetable. This may be due to the inherent adaptation of the crops as the maize being more exhaustive crop, and being nullified by the *rajmash* by nitrogen fixation.

5.2.3 Understanding farmers' perception and varietal attributes of *rajmash* in the study area

The farmers' generally prefer small red seed, with kidney shape and plain coated seed which is due to the advantage of good market value of the red type of seed. The farmers prefer varieties having good taste, swelling and less time on cooking. Regarding specification of new varieties for low production potential system of Kashmir valley, farmers' showed their willingness for the varieties possessing high yield, drought/disease resistance and varieties with good market value. In traditional farming the Farmers' variety and seed management practices remained very much effective in achieving goals of adaptation and genetic gain in terms of yield but also in terms of maintaining ritual, culinary and market traits

(Cleveland and Soleri, 2007). The Farmers maintain their varietal ideotypes and changing or creating more preferred genotypes or variants in the informal seed system (Berthaud *et al.*, 2001; Soleri and Cleveland, 2001). In the informal seed system, there are specialized farmer-selectors (Almekinders and Elings, 2001; Cleveland and Soleri, 2007). However, not only the specialized farmers who make up an informal seed system, but most of the farmers engage in one way or another in seed production, seed diffusion and in designing new farming systems simultaneously (Offei *et al.*, 2010). Most of the farmers prefer early maturing varieties in *rajmash* in order to avoid the damage caused by the terminal drought at later growth stages in the rainfed areas. However substantial number of farmers' also prefers uniform harvest in order to save the labour for various pickings.

5.2.4 Variability analysis in *Rajmash* genotypes

The success of any breeding programme depends on the presence of sufficient variability to pursue effective selection. Therefore the study of genetic variability and its effective utilization is a fundamental tool for crop improvement programmes. Ample germplasm resources are available in the form of farmers' adapted landraces, collections in national and international gene banks which can be used for identification and development of high yielding bean cultivars. Singh (2001) stated that very little variability available in different gene pools of common bean has been utilized for crop improvement. A number of studies have been conducted to characterize the variability in common bean for yield and morphological traits to develop pre-breeding material for appropriate breeding strategies for developing high yielding varieties (Peksen, 2007; Sofi *et al.*, 2011; Amanullah and Muhammad, 2011). Substantial variability for morphological, maturity and yield traits in local Kashmiri *rajmash* has been reported by many workers (Razvi *et al.*, 2012; Sofi *et al.*, 2014; Sultan *et al.*, 2014).

The 54 genotypes comprising of both pole and bush types exhibited substantial variability for all quantitative traits studied except in case of pole types

were plant height was non-significant and in bush types were number of pods per plant was non-significant. Therefore the material can be used in breeding programmes based on trait based selection for selecting desirable genotypes for different traits for use in future breeding programme.

5.2.5 Evaluation of *rajmash* genotypes on farmers' field using farmers' 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, 1996; 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, 1995).

Hence in present investigation, evaluation of mother trials through farmer's preferential ranking of different genotypes was carried out. At the time of pod maturity when *rajmash* pods were at edible stage, farm walks and 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.

5.3 Preferential ranking of Pole type of *rajmash*

Thirty one genotypes were selected from the material and were laid at four

locations in three districts namely Warnov, Kupwara, Hajibal Baramulla, Sumlar Bandipora and Regional Research Station Wadura Sopore. The farmers' responded overwhelmingly and there were many genotypes which carry the farmers' attention but few were most promising lines. At the village Warnov Kupwara highest preferential scoring was for the genotype WB-83 and the lowest preference was recorded for WB-224 followed by WB-330. It was due to overwhelming response of farmers towards the variety having more number of pods per plant and seed yield per plot. Similarly at village Hajibal Baramulla maximum scoring was recorded for WB-83. At village Sumlar Bandipora district WB-83, WB-258, WB-1011, WB-450, WB-38, received maximum number of votes as preferred by the farmers'. At Research Station Wadura Sopore the genotype WB-83 (1), WB-258 (1), WB-1012 (1), have maximum preferential scoring followed by WB-38(2), WB-143(3). The farmers selected these varieties because of certain desirable characteristics as that may be high number of pods per plant, high grain yield, high seed yield and early maturity.

Lowest cumulative rank of a particular genotype with highest pooled preference indicates that the variety is the most preferred one. The variety WB-83 with mean preference rank of 1.6, WB-222 identified as second best (1.8) followed by WB-1011 (1.9), WB-38 (2.4) and WB-258 (3.2). The genotypes WB-184, WB-258-1 and WB-330, WB-255 were statistically at par in term of rank summation index.

The reasons for the preference were related to many traits including seed shape, size and colour, early maturity, high seed yield, taste and swelling and free from diseases as per the interviews.

5.4 Preferential ranking of bush type of *rajmash*

Twenty three genotypes were selected from the material and were laid at four locations in three districts namely Langate Kupwara, Rohama Baramulla, Malangam Bandipora and Regional Research Station Wadura Sopore. The

farmers' responded overwhelmingly and there were many genotypes which carry the farmers' attention but few were most promising lines. At the village Longate Kupwara highest preferential scoring was recorded on WB-185(1). The lowest preference was recorded for WB-479 followed by WB-490. Similarly at village Rohama in Baramulla district maximum scoring was recorded for WB-147, WB-185 and Shalimar Rajmash-1. At village Malangam Bandipora district WB-185, WB-147, Shalimar Rajmash-1, WB-966, WB-195 received maximum number of votes as preferred by the farmers'. At Research Station Wadura Sopore the genotype WB-185, WB-147, WB-209 had maximum preferential scoring followed by Shalimar Rajmash-1 and WB-966. The farmers selected these varieties because of certain desirable characteristics as that may be high number of pods per plant, high grain yield, high seed yield and early maturity.

Lowest cumulative rank of a particular genotype with highest pooled preference indicates that the variety is the most preferred one. The variety WB-185 identified as the best variety with rank 1 and preferential score equal to 1, WB-147 (5, 0.3) identified as second best followed by WB-966 (3, 0.6), Shalimar Rajmash-1(3, 0.6) and WB-195 (2, 0.8). Generally farmers selected on the basis of yield and yield attributing traits with earlier maturity. Genotypes WB-22, WB-209 and WB-223 were statistically at par in term of rank summation index. The lowest preference was recorded for WB-490 followed by WB-54. The reasons for the preference were related to many traits including seed shape, size and colour, early maturity, high seed yield, taste and swelling and free from diseases as per the interviews.

From the preferential ranking of pole and bush type of *rajmash* varieties at different locations, varieties WB-38, WB-83, WB-258, WB-222 and WB-1011 from the pole type, varieties WB-966, WB-22, WB-147, WB-195, WB-185, WB-209 and Shalimar Rajmash-1 from the bush type were selected by the farmers' as these varieties were having desirable preferential score. From among these only six were selected for baby trial evaluation at 20 different locations.

Further significant interaction between varieties and locations for the preferences ranking was recorded. In fact Witcombe *et al.* (2005) has reported that most of the variations in ranking between sites occur for the lower ranked varieties (Witcombe *et al.*, 2005). He critically analyzed the participatory techniques to rice varieties derived from client oriented breeding programmes through Mother and baby trials system in Bangladesh. The rapid acceptance of these varieties by farmers' illustrates the power of participatory trial system. Gyawali *et al.* (2005) screened 142 accessions through collaborative selection for quality varieties and few were finally proven to be generally superior for post harvest traits in Pokhara valley of Nepal using local preferences and selection (Joshi *et al.*, 2007). And Tiwari *et al.* 2009 using Mother and Baby trial design, led to release of population 22 in 2002 through preferences by farmers' that had previously escaped identification.

5.5 Analysis of Genotype $\times$ Location ($G \times L$) interaction and Stability Studies by Eberhart and Russell model (1966).

In the present study stability parameters such as mean ($\bar{X}$), regression coefficient (b_i) and deviation from regression (S_{di}^2), as suggested by Eberhart and Russell (1966) were considered to explain and discuss the stability of different genotypes for various characters under consideration. Analysis of variance for stability in the performance of different genotypes across four random environments revealed that the mean squares due to genotypes were highly significant for all the traits viz., days to 50 per cent flowering, days to maturity, plant height, number of pods plant⁻¹, pod length (cm), number of seeds pod⁻¹, pod yield plant⁻¹, seed yield plot⁻¹ and 100 seed weight. The material selected were thus divergent and possessed significant genetic variation for all traits. Environments selected revealed significant differences for the expression of days to 50 per cent flowering, days to maturity, plant height, pods plant⁻¹, pod length, number of seeds pod⁻¹, pod yield plant⁻¹, seed yield plot⁻¹ and 100 seed weight, confirming that the environments selected were variable and random and

influenced the expression of most of the traits selected for the stability studies. Mean squares arising due to genotype $\times$ Environment (G $\times$ E) interaction revealed that variance ratio was significant for all the traits indicating thereby that the genotypes were having, by and large, significant differential response to the changing environments. The environment + (genotype $\times$ environment) mean were significant for all the traits. However, partitioning this variance into components like environments, environments (linear), genotype $\times$ environment (linear) and pooled deviation (non-linear) revealed that mean squares due to environment (linear) were highly significant for days to 50% flowering, days to maturity, plant height, pods plant⁻¹, pod length, number of seeds pod⁻¹, pod yield plant⁻¹, seed yield plot⁻¹ and 100-seed weight. The significant mean squares confirmed that the environment were random and different and they exercised influence on the expression of a trait having significant mean squares and this variation could be attributed to have arisen due to linear response of the expression of the genotypes to the environment. The mean squares due to G $\times$ E (linear) were significant for days to 50% flowering, days to maturity, plant height, pods plant⁻¹, pod length, number of seeds pod⁻¹, pod yield plant⁻¹, seed yield plot⁻¹ and 100-seed weight, revealing that the behaviour of the genotypes could be predicted for environments more precisely for most of the traits and the G $\times$ E interaction was the outcome of the linear function of the environmental components.

The non-linear component arising due to heterogeneity, measured as mean squares due to pooled deviation, was significant for days to 50% flowering, days to maturity, plant height, pod length, number of pods plant plant⁻¹, number of seeds pod⁻¹, seed yield plot⁻¹ and 100-seed weight. These significant mean squares revealed presence of non-linear response of the genotypes to the changing environments (stability performance). The significant mean squares for the pooled deviation confirmed contribution of non-linear component total G $\times$ E interaction. The genotypes differed with respect to the stability for these traits making its prediction more difficult. 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 $\times$ 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 genotype 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 $G \times E$ 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 Russell (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 $\times$ 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 both pole and bush type of genotypes including farmer's variety as checks were estimated to identify the most suitable genotypes across a range of environments and for suitable environments. 31 genotypes from the pole types evaluated across four random environments and 23 genotypes from the bush types evaluated also across different four random environments for morphological (days to 50% flowering, days to maturity, plant height) yield components (pods plant⁻¹, pod

length, number of seeds pod⁻¹, 100-seed weight) and yield (pod yield plant⁻¹, seed yield plot⁻¹) across four random environments for both bush and pole type.

5.5.1 Stability analysis for Pole type of *rajmash*

The stability parameters estimated were mean of the trait ($\bar{X}$), linear regression (b_i) mean square deviation from regression (S_{di}^2), where $\bar{X}$ provides a measure of the performance of a variety as compared to other entries, the b_i and S_{di}^2 values are the measure of the $G \times E$ interaction. The components S_{di}^2 measures predictability and the component b_i measure the stability. In general, if $G \times E$ is non-significant or where this $G \times E$ interaction is either linear or predominantly linear as compared to its non-linear component, the prediction of stability of a genotype over environments becomes more reliable. As per the Eberhart and Russel's model of stability, the component S_{di}^2 measures predictability and b_i the stability. Stability of a genotype can be predicted more precisely if $G \times E$ interaction and S_{di}^2 value are non-significant.

The analysis of variance table shows that the genotypes differ significantly across locations. The mean squares of all the characters show significant change. However there were few genotypes among the pole types which fulfil the criteria as per the condition of Eberhart and Russell (1966) model to be stable across the environments. Genotypes WB-38, 83, 258 were having mean of days to 50% flowering less than the population mean and b_i and S_{di}^2 equal to 0.7, 0.8, 0.9 and 0.2, 0.5, 0.4 respectively. The days taken to maturity also show the mean of Genotypes WB-38, 83, 258 less than the average mean. The characters pods plant⁻¹, pod length, number of seeds pod⁻¹, 100-seed weight, pod yield plant⁻¹, seed yield plot⁻¹ of the genotypes WB-38, 83, 258 are having mean greater than the average mean and the value of b_i and S_{di}^2 indicate that the varieties are stable across various locations. All the cultivars showing non-significant deviation from regression (S_{di}^2) and regression coefficient (b_i) were average in stability and poorly or well adapted to the environments.

5.5.2 Stability analysis for Bush type of *rajmash*

The stability parameters estimated for bush type of *rajmash* were mean of the trait ($\bar{X}$), linear regression (bi) mean square deviation from regression (S_{di}^2), where $\bar{X}$ provides a measure of the performance of a variety as compared to other entries, the bi and S_{di}^2 values are the measure of the $G \times E$ interaction. The components S_{di}^2 measures predictability and the component bi measure the stability. In general, if $G \times E$ is non-significant or where this $G \times E$ interaction is either linear or predominantly linear as compared to its non-linear component, the prediction of stability of a genotype over environments becomes more reliable. As per the Eberhart and Russell's model of stability, the component S_{di}^2 measures predictability and bi the stability. Stability of a genotype can be predicted more precisely if $G \times E$ interaction and S_{di}^2 value are non-significant.

The analysis of variance of bush type of *rajmash* shows that the genotypes differ significantly across locations. The mean squares of all the characters show significant change. However there were few genotypes among the bush types which fulfil the criteria of stability as per the condition of Eberhart and Russell (1966) model to be stable across the environments. Genotypes WB-195, 185, 966, 147, 185 and Shalimar Rajmash-1 were having mean days to 50% flowering less than the population mean and bi and S_{di}^2 equal to 1.3, -3.0, 1.4, 1, 1, 0.6 and 0.3, 0.7, 0.7, 0.8, 0.03, 0.5 respectively. The days taken to maturity also show the mean of Genotypes WB-195, 185, 966, 147, 185 and Shalimar Rajmash-1 less than the average mean. The characters pods plant⁻¹, pod length, number of seeds pod⁻¹, 100-seed weight, pod yield plant⁻¹, seed yield plot⁻¹ of the genotypes WB-195, 185, 966, 147, 185 and Shalimar Rajmash-1 are having mean greater than the average mean and the value of bi and S_{di}^2 indicate that the varieties are stable across various locations. All the cultivars showing non-significant deviation from regression (S_{di}^2) and regression coefficient (bi) were average in stability and poorly or well adapted to the environments.

So in total six genotypes were selected on the basis of preferential ranking

and stability analysis both from the bush and the pole types for evaluation in the baby trials. Genotypes WB-83 and WB-258 from the pole types and WB-185, WB-195, WB-966 and Shalimar Rajmash-1 were selected from the bush type.

Despite the estimation of stability based on linear regression coefficient and deviation from linearity on physiological grounds was estimated by Knight (1970), nevertheless, the biometrical model given by, Eberhart and Russell (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.

5.6 Baby trials

The mother and baby trial system recognizes the difficulty of obtaining reliable yield data from many, widely dispersed participatory trials, so in baby trials only farmers' perceptions on yield is collected. A farmer grows one new variety alongside the local variety under the customary management practices. Replication is across farmers', either in the same village or across villages. Even if there are many new varieties, only one is tested by any one farmer. The trials are evaluated by participatory methods, farm walks and Focused Group Discussions. Qualitative data (for example, on yield) are obtained by project fellows from interviews with farmers'.

PVS is now widely used and accepted. For example, Atlin (2003) states that all breeding programmes should include participatory on-farm trials. Weltzien *et al.* (2003) report that most cases of PPB they reviewed were only employing PVS. However, there are many ways of carrying out highly participatory trials. Private-sector breeders use strip trials in which each entry occupies a single strip of land across the farmer's field. The public sector employs some form of a mother and baby trials system (Snapp, 1999). However, they may not have always

been referred to in that way. For example, the trials system used by Joshi and Witcombe (1996) consisted entirely of baby trials and it was called farmer-managed participatory research (FAMPAR).

In Asia, more densely populated villages allow more trials to be managed and this makes a simple, single-replicate design efficient. The decision is based on the most cost-effective way of increasing replicates, either more farmers' or more replicates with each farmer. For example, Dofing and Francis (1990) working on sorghum in the United States recommended that one replicate trial should be used at as many locations as can be afforded, as long as the cost of an additional location relative to the cost of an additional replication is not excessive. The methodology presented by them allows the researcher to determine the efficiency of one-replicate testing for a programme while varying location and replication costs. Johnson *et al.* (1992) looked at the trade-off between replications within a site and additional locations with fewer replications.

There were twenty (20) baby trials laid during the year 2014, across the three districts of North Kashmir. The farmers' perceptions about the six *rajmash* varieties selected from the mother trial, were assessed in the baby trials through farm walk and focused group discussions. The six varieties (WB-185, WB-83, WB-195, WB-966, WB-258, and Shalimar Rajmash-1) were compared with the farmers' local check for various yield and yield attributing traits viz., days to flowering, days to maturity, number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot. These varieties vary considerably in different traits with each other and with the local check.

Variety WB-185 showed days to 50% flowering and days taken to maturity almost same as compared to check, hence requires the same number of days for maturity and crop harvest. However the farmers' reflect that the variety is having more number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check, reflecting that the variety is having more yield potential than the check.

Variety Shalimar Rajmash-1 showed days to 50% flowering is almost same as compared to check and days taken to maturity is more as compared to check, indicating that, inspite of having same days to 50% flowering, the variety takes more time for grain filling and hence matures late. When compared with the variety WB-185, it takes more time for maturity. However the farmers' preferences and voting reflected that the variety is having almost same number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check, which reflected that more time for grain filling does not enhance any yield potential. So it is having less yield potential than the variety WB-185. So it reflected that the variety is almost same as compared to the local check and is not desirable in all the yield attributing traits. The variety is not favoured also because of more damage due to susceptibility to bean common mosaic virus.

Variety WB-966 showed that the traits vary considerably among themselves between more, same and less. Substantial number of farmers' reflect that days to 50% flowering is almost less as compared to check and days taken to maturity is more as compared to check, which indicated that inspite of, the variety taking less days to 50% flowering, it matures late than the check. So it is hereby reflected that a variety a variety having less days to 50% flowering does not mean that the variety matures early or the days taken to maturity is decreased. However, the farmers' reflected that the variety is having almost same number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check. So it reflected that the variety was not desirable than the check as such in all the yield attributing traits, but can be grown as few yield attributing traits are more tilted towards the variety in yield compared to the check.

WB-83 takes less time for days to 50% flowering as compared to and days to maturity was less as compared to check. The variety is having both days to 50% flowering and days taken to maturity less as compared to check and hence was desired. It was the variety which was having both these traits favourable among all other compared varieties and the local check. However the farmers' reflect that

the variety is having more number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check. So it reflected that the variety is more desirable than the check in all the yield attributing traits.

Variety WB-258 showed that, the vote in favour of different traits varies considerably among themselves between more, same and less. Substantial number of farmers' reflected that days to 50% flowering is almost same as compared to check while as 94.02% of farmers' voted that, days taken to maturity is same as compared to check, making the duration for crop harvest same as compared to local check. However the farmers' in general reflect that the variety is having almost same number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check. So it reflected that the percentage response of farmers' regarding the variety vary considerably among different traits, hence the variety is not as such desirable than the check in all the yield attributing traits, but can be grown as few yield attributing traits are more tilted towards the variety compared to the check.

Variety WB-195 showed days to 50% flowering same as compared to check as substantial number of famers' vote in this favour while as maximum number of farmers' voted that, days taken to maturity of the variety is same as compared to check, which reflected that the variety takes same duration for harvest. However the farmers' reflect that the variety is having more number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot than the check. So from the data and table it reflects that the variety is more desirable than the check in all the yield attributing traits.

So the above discussion results that out of the six genotypes (WB-185, WB-83, WB-195, WB-966, WB-258, and Shalimar *Rajmash*-1) selected from the mother trial only three (WB-185, WB-83, WB-195) seems to be better than the local check and other three varieties (WB-966, WB-258, and Shalimar *Rajmash*-1). The finally selected three varieties from the baby trial are having the desirable traits as, days to 50% flowering and days taken for maturity less than the average,

the mean of number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot being higher than the average mean of the local farmers' check and the other three mother selected genotypes.

The present study revealed that, it is therefore recommended that the genotypes WB-185, WB-83 and WB-195 should be extensively tested in farmers fields for further evaluation as well as concomitant seed multiplication, so that the variety goes into production chain. It would be desirable to encourage participant farmers to take up seed production, so that local systems are strengthened.

Chapter-6

SUMMARY AND CONCLUSION

The present investigation entitled. “Participatory Varietal Selection in Rajmash (*Phaseolus vulgaris* L.), Through mother-baby trial evaluation system in Baramulla, Bandipora and Kupwara districts of Kashmir” was a part of initiative taken by SKUAST Kashmir in order to bring farmer and farming system characteristics into the mainstream varietal development process to add relevance to the varieties so that the adoption is more speedy and the varieties can meet the aspirations of target farmers’. Under this programme, three crops namely rice maize and *rajmash* were identified for starting participatory varietal selection. The major components of the present study were identification of farm and non –farm attributes of *rajmash* based farming systems; assessment of farmers’ preferences and varietal attributes and testing of material on farmers fields under his management practices for identification of farmer preferred genotypes.

In order to assess the farm and non-farm characteristics of *rajmash* based farming systems, a PRA was undertaken in three districts namely Baramulla, Bandipora and Kupwara using a structured questionnaire that sought to develop baseline information about the farming systems, production constraints, varietal specifications and livelihood opportunities. The major outcomes of PRA were:-

6.1 Farming system characteristics

- *Rajmash* is the major summer season pulse crop of Kashmir Valley.
- Mixed cropping is largely in vogue (79.34%) and *rajmash* is seldom grown as a sole crop. It is grown in mixtures along with maize, potato and vegetables.
- Crop is invariably grown as rainfed (70.3%).
- Farmers saved seed is the major source of seed (78.10%) with institutional support as little as (21.90%).

6.2 Production constraints

- Low yield of existing varieties. Even the variety released by the university namely Shalimar Rajmash-1 has yield potential of 1-1.2 t/ha under optimum management.
- Drought stress (73.10%) that strikes as early, intermittent and terminal drought is the major abiotic stress, limiting yield of *rajmash*.
- Diseases namely BCMV, Anthracnose, Angular leaf spot etc. (68.27%) are major biotic stresses and existing varieties are highly susceptible. Especially in case of BCMV, which is a seed borne disease; continuation of farmers' own saved seed ensures that disease comes in mild or severe form every year depending upon environmental conditions.

6.3 Varietal specifications

- Pole type varieties that could fit into mixed cropping system are preferred.
- Small seed with red colour were invariably preferred owing to its greater market value (50%).
- Early maturity was a preferred trait (87.04%), since it helps farmers' avoid the terminal drought especially in the months of June and July which are largely hot and dry.
- Early to cook and taste are preferred attributes in view of the energy issues (56.20%) market value as well as the cultural attributes associated with the crop.

Based on the attributes, 54 breeding lines including the university released variety were tested through mother-baby trial system of evaluation at the Research Station and the farmers' field across six locations for mother trial and across 20 locations in case of baby trials in three districts. The varieties were evaluated for

yield and other parameters as well as stability across environments in order to identify desirable genotypes that could be promoted through baby trials. The major findings of the mother and baby trials were:-

A) Variability

Both pole and bush type of genotypes exhibited substantial variability for all quantitative traits studied except in case of pole types where plant height was non-significant and in bush types where number of pods per plant was non-significant. Therefore the material can be used in breeding programmes based on trait based selection for selecting desirable genotypes for different traits for use in future breeding programme.

B) Preferential index

The preferential scoring of test genotypes revealed that most preferred genotype on the basis of lowest cumulative rank and highest preferential score among pole types was WB-258 with mean preference rank of (3.2) followed by WB-38 with mean preference rank of (2.4), WB-83 (1.6), WB-222 (1.8) and WB-1011 with mean preference rank of (1.9). The genotype that received maximum number of negative votes was WB-1115 (-2.6). Among bush type of *rajmash* the most preferred were WB-185 with mean preference rank of (3.8) followed by WB-147 with mean preference rank of (3.3), Shalimar *Rajmash*-1 (3.1), WB-966 (3.05) and WB-195 with mean preference rank of (2.3). The genotype that received maximum number of negative votes was WB-490 (-2.5). Farmer's variety was the least preferred variety and was at par with the test genotype WB-966, WB-258 and Shalimar *Rajmash*-1. Also genotypes WB-38, WB-222, WB-1011 among pole types and WB-147, WB-22 among bush type were statistically found at below in term of mean preference when compared by the farmers'.

C) Stability

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 $\times$ environment) were significant for most of the traits except days to 50% flowering and days to maturity depicted the distinct nature of environment and genotype $\times$ environment interaction on phenotypic expression. Genotype $\times$ environment (linear) interaction component showed non-significance only for plant height whereas, all other traits showed high significance indicating location (environment) had a marked influence on the expression among the genotypes and behaviour of the genotypes could be predicted more precisely over environment. 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 found highly significant except pod length. Pooled deviation for all the traits was found significant suggested that the performance of different genotypes fluctuated significantly from their respective linear path of response to environments.

On the basis of stability parameters genotypes WB-83, WB-258 among pole and WB-185, WB-195, WB-966 and Shalimar Rajmash-1 were identified as the most stable genotypes for seed yield per plot across all locations on the basis of high mean performance and non-significant estimates of b_i and S_{di}^2 from unit and zero respectively, however latter genotype showed sensitivity to better environments for biological yield on the basis of significant b_i estimates. Similarly these genotypes were identified as consistent for early flowering for all the locations.

D) Better varieties

The elite genotypes revealed that performance could be predicted across environments because all these genotypes had expressed significant deviation from regression (S_{di}^2) for the most of traits. Some of the genotypes like WB-185, WB-195, Shalimar Rajmash-1 and WB-83 possessed high yielding and performed well across the environments. From both participatory varietal selection and Stability analysis genotypes viz. WB-195, WB-185, WB-966, Shalimar Rajmash-

1, WB-83 and WB-258 were further evaluated in baby trials as these genotypes were stable for most of the traits across environments and got highest preferential score in Participatory varietal selection. The genotypes viz. Shalimar Rajmash-1, WB-185, WB-966, Shalimar Rajmash-1, WB-83, WB-258 were evaluated in baby trials and out of these six only three were preferred (WB-185, WB-83, WB-195) across various locations, based on the pair wise comparison method of various traits between these varieties and the local check.

E) Baby trial

The farmers' perceptions about the six *rajmash* varieties which were selected from the mother trial were assessed through the focused group discussions. The six varieties (WB-185, WB-83, WB-195, WB-966, WB-258, and Shalimar Rajmash-1) were compared with the farmers' local check for various yield and yield attributing traits. Viz., days to flowering, days to maturity, number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot. These varieties vary considerably in different traits with each other and with the local check. On the basis of the comparison of the important yield attributing traits WB-83 was having less days to 50% flowering, days to maturity and was having highest percentage of farmers' favouring the variety on the basis of maximum number of pods per plant, pod yield per plant, seeds per pod and seed yield per plot. The 83 was followed by the varieties 195 and 185 which also get maximum favour from farmers' when compared with other genotypes and the farmers' check.

Roadmap for future

While institutional efforts on part of SKUAST-Kashmir and development departments have led to considerable diffusion of modern high yielding varieties in case of rice, maize and wheat, the situation is not so encouraging in pulses in general and *rajmash* in particular, with little or no impact of released varieties. The disproportionate impact of modern varieties is largely due to the inherent

bottlenecks of low input small holder farming system of which *rajmash* is an important component in Kashmir valley. The attributes of such farming systems are both farm and non-farm and most of the times plant breeders have failed to appreciate the non-farm attributes, such as the socio-economic status, market opportunities and consumer preferences. This disconnection between the existing research priorities and the real world problems need to be bridged in order to overcome the risks associated with such disconnect.

PPB has evolved as a socially responsible effort in plant breeding in order to connect the farmer, his situations as well as the future challenges to research priorities of national and international breeding efforts. Even if the experience of PPB in *rajmash* has been worth the effort, there is a need to strengthen the linking mechanisms to build a knowledge based for addressing current production constraints, harness the niches status of the crops as well as enhance the adaptive capacity of small *rajmash* farmers to future challenges. There are strong ecological, economical and social imperatives of such linkage. However major goal should be to enhance the farmers to be able to harness the livelihood opportunities, promote conservation through use and link gene banks to farmers needs as well as make them future ready. There is a growing demand for local niche crop based food that can provide new opportunities to small farmers'. There is a need to optimize different channels from production to consumption. Plant breeders have a strong role to develop varieties that are able to enable the farmers to harness the benefits.

Therefore while, as plant breeders as we re-orient our breeding programmes we should understand the farmer a socioeconomic status, his production constraints, his excess to resources as well as opportunities he has. There is a need to put farmer first in our breeding goals and then think beyond our obsession with yield. We need to identify the constraints and preferences of farmers and accordingly prioritize our researchable issues.

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ANNEXURE-I

QUESTIONNAIRE DESIGNED FOR PRA IN COMMON BEAN

Rajmash Variety Evaluation Questionnaire

DISTRICT:- _____

LOCATION:- _____

S. NO.	ATTRIBUTE/TRAIT	RANKING /SCALES/OPTIONS	RESPONSE
1	RANKING OF RAJMASH AMONG KHARIF PULSES	1-N	
2	FARMING PRACTICES	1. SOLE CROP 2. MIXED CROP	
3	IRRIGATION SYSTEM	1. ASSURED IRRIGATION 2. RAINFED	
4	SOURCE OF SEED	1- FARMERS SAVED SEED 2- INSTITUTION/UNIVERSITY 3- ANY OTHER	
5	COLOUR OF SEED	1- SMALL RED 2- KIDNEY RED 3- OTHERS	
6	SEED COAT PATTERN	1- PLAIN 2- MOTTLED	
7	SEED SHAPE	1- KIDNEY 2- OVAL 3- OTHERS	
8	MATURITY	1. EARLINESS 2. UNIFORM HARVEST	
9	BIOTIC STRESS	1. DISEASE RESISTANCE 2. INSECT RESISTANCE 3. WEED RESISTANCE	
10	ABIOTIC STRESS	1. DROUGHT TOLERANCE 2. COLD TOLERANCE 3. OTHERS	
11	YIELD	1. GRAIN YIELD 2. POD LOAD 3. OTHERS	
12	MARKET	1. SEED SIZE 2. SEED SHAPE 3. OTHERS	
13	CULINARY	1. COOKING TIME 2. SWELLING 3. TASTE 4. OTHERS	

ANNEXURE II

AGRICULTURE PROFILE OF THE THREE DISTRICTS OF NORTH KASHMIR

DISTRICTS	Total Geographical Area	Cultivable Area	Net Sown Area	Gross Cropped Area	Cropping Intensity (%)	Area Under Rajmash	Geographical Coordinates		
							Latitude	Longitude	Altitude
KUPWARA	66.59	45.65	45.65	51.17	112	0.511	75 ⁰ 31 N	74 ⁰ 15'E	5371 ft
BARAMULLA	109.47	64.85	64.85	67.14	103	0.300	34.12 ⁰ N	74.20 ⁰ E	5207 ft
BANDIPORA	34.28	20.34	20.56	21.78	116	1.758	34 ⁰ -25N	74 ⁰ 38'E	5541 ft

Source :- Department of Agriculture, Government of Jammu and Kashmir

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

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. D.K. Verma, Principal Scientist, IGFR, Srinagar during Viva-Voce examination held on September 2, 2015 have been incorporated in the manuscript entitled **“Participatory Varietal Selection in Rajmash (*Phaseolus vulgaris* L.) through mother-baby trial evaluation system in Baramulla, Bandipora and Kupwara districts of Kashmir”** submitted by **Mr. Fayaz Ahmad Shiekh (Regd. No. 2012-413-D)**.

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