"STUDIES ON SEED QUALITY PARAMETERS IN DIFFERENT GENERATIONS OF FINGER MILLET (*Eleusine coracana* (L) Gaertn.)"

THESIS

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KALYANRAO

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Kalyanrao
(Author)

Dr. Rajendra Prasad
Professor& Head

Department of Seed Science & Tech
College of Forestry & Hill Agriculture
G. B. Pant University of Agri. & Tech.,
Hill Campus, Ranichauri-249199
Distt. Tehri Garhwal, Uttarakhand, India

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON SEED QUALITY PARAMETERS IN DIFFERENT GENERATIONS OF FINGER MILLET (*Eleusine coracana* (L) Gaertn.)",** submitted in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** with major in **Seed Science and Technology** of the college of Post-Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Kalyanrao**, **Id. No. 32878,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation has been acknowledged.

(Rajendra Prasad)
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Kalyanrao, Id. No. 32878,** a candidate for the degree of **Master of Science in Agriculture** with major in **Seed Science and Technology**, agree that the thesis entitled **"STUDIES ON SEED QUALITY PARAMETERS IN DIFFERENT GENERATIONS OF FINGER MILLET (*Eleusine coracana* (L) Gaertn.)"** may be submitted in partial fulfilment of the requirements for the degree.

(Rajendra Prasad)
Chairman

(Deepa Khulbe)
Member

(Vijay Kumar Yadav)
Member

CONTENTS

CHAPTER I

INTRODUCTION

Millets are small seeded annual cereal grasses, belonging to the grass family "Poaceae" Seeds of millets are used for food, feed and forage all over the world particularly in tropical, sub tropical and certain parts of the warm temperate area of the world. These are distributed in about 10 genera and 20 species in all. Except for sorghum and pearl millet all other millets grouped under small millets. Small millets are generally considered as minor crops except in parts of Asia, Africa and former USSR. India is considered as a hub for these minor crops, as large number of small millets are grown in different part of the country, starting from sea level in South up to 10,000 ft altitude in North particularly in Himalaya and North Eastern hills. However, six millets viz; finger millet, barnyard millet, foxtail millet, proso millet, kodo millet and little millet are most important small millet crops, in view of their area and production in different parts of the country. Amongst small millets, finger millet also known as Ragi accounts for 8 per cent of the area and 11 per cent production of all the small millets cultivation in the world (Bennetzen, *et al*. 2003). In India, finger millet accounts for 60 per cent area and three fourth of total small millets production (Kumar *et al*.2007)

Finger millet was probably first introduced in India around second millennium BC through sea trading from Africa (Hornell, 1941), thus established India as secondary center of origin. Strictly North Indian and North

Indian high land types grown in North and North-Eastern parts do not share direct introduction to India. Low-land races, after their introduction in southern coastal area, probably underwent modification for adoption in North and North-Eastern Himalayan region movement. However, origin of North Indian high-land races is not clear (Hillu and de-Wet, 1976).

Ragi is a staple food rich in calcium, iron, and protein and also good for infants and diabetic patients. It is also used in many preparations like cakes, pudding, sweets, malts etc. The protein content ranges from 8 to 11 per cent which is very well comparable with other fine grain cereals. The average fibre content in ragi varies from 3 to 6 per cent unlike 0.2 per cent in rice or 1.2 per cent in bajra. It is also believed to prevent high cholesterol content and intestinal cancer. The carbohydrate content in ragi is about 72 per cent which is slightly higher compared to bajra and maize and lower than rice. The slow release of energy result lesser accumulation of glucose in the blood which is beneficial to diabetic patients. Besides, the seeds are not easily affected by storage pests and diseases hence it can be stored for longer period.

Ragi is grown for grain and fodder purpose under varied agro climatic conditions. In India it is grown in an area of about 15.40 lakh ha with production of 22.9lakh tonnes. Karnataka state ranks first both in acreage (9.3 lakh ha) and production (16.1 lakh tonnes). In India other ragi growing states are Tamil Nadu, Maharashtra, Uttarakhand, Gujarat, Orissa, Bihar and Himanchal Pradesh. (Anon, 2005).

In Uttarakhand, finger millet is the second most important crop after rice among *kharif* crops both in terms of acreage and production in, The hill region of the state. It is cultivated in an area of 140 thousand hectares, (which is 14 % of total cultivable area), with a production of 174 thousand tones (12.13% in total cereal production). The crop is largely grown in harsh and fragile environments, with minimal use of agricultural inputs due to its remarkable ability to withstand erratic rainfall and varying weather conditions it is a regular crop up to 2,300 m msl during *kharif* season in Uttarakhand and form main stay of agricultural diet and cultural system of hill people. (Kumar *et al.*2007)

Seed material is an important input in agriculture production. Ragi crop is grown in all the seasons both under rainfed and irrigated conditions. In view of increase in the acreage of ragi, there is greater demand for quality seeds. Generally the crop is harvested when the colour of the earhead of the grain pigmented varieties turn yellow and the dull grey in purple types. Considerable field losses are caused due to shedding, damage by birds and rodents and deterioration in seed quality affects the germination and vigour. Considerable variations among the varieties are observed in respect to stage of harvest, season weather conditions and cultural practices (Ramaiah and Rao, 1953).

Genetic variation from the traditional land races and wild species is important because it provide a gene pool which has developed natural resistance to pest and other environmental stresses, over time, and will help in the future survival of important food crops. Thus, a broad genetic base is the key to improvement of finger millet and also an insurance against natural vagaries Assemblage of genetic variation and identification of useful genes is a pre- requisite to attain any breeding objective

Ragi ($2n = 4x= 36$) is a highly self pollinated crop. Crossing is difficult so that, use Presence of genetic male sterility will make crossing easier in finger millet. Genetic male sterility in finger millet was first reported in Uganda (Odella, 1993) and used to study heterosis and develop random mating populations. Gupta *et al*. (1997) at ICRISAT developed a new genetic male sterile line of finger millet (INFM 95001) by mutation.

The hybridization programme started at Hill Campus GBPUA&T, Ranichauri by involving genetic male sterility line INFM 95001 procured from ICRISAT in 2003, which is of African origin. GMS line was crossed with well adopted local lines and early maturing, disease resistant local lines for broadening the genetic base. The crossing and advancing of generations are being carried out both field and glass house conditions. Efforts made so for have resulted in advancement of generation to F_7 and selection of homozygous amber grain lines.

Ragi offers large scope for improvement through hybridization of divergent parents programme. There are several high yielding varieties available in different region. The importance of F_1 hybrids for increasing yield and uniformity is well known as hence, the production of hybrid finger millet technique is becoming popular after the introduction of male sterile INFM 95001 line.

"Keeping in view the importance of seed quality maintenance of parental lines and assessment of hybrid parents, present investigation was under taken with the following objectives."

1. To study field and seed standards of GMS line and Gaja local line.
2. To assess the heterosis and heterobeltiosis.
3. To compare the seed quality parameters of different generations.
4. To study the relationship between various morpho-physiological characters of different generations.

REVIEW OF LITERATURE

Seed is the basic unit of maintenance and distribution of plant population, which carries the genetic identity of the crop plant, determining the upper limit on yield and other characters. The literature relevant to the present investigation entitled “STUDIES ON SEED QUALITY PARAMETERS IN DIFFERENT GENERATIONS OF FINGER MILLET (*Eleusine coracana* (L) Gaertn.)” is limited, thus an attempt has been made to include work done in other related crops under the following sub headings:

2.1 Qualitative characters

2.2 Mean performance and variability

2.3 Heterosis studies

2.4 Seed quality parameters

2.4.1 Germination studies

2.4.2 Seed viability and seed vigour component

2.5 Studies related to different generations

2.6 Characters association

2.1 Qualitative characters

Il´in, (1984) presented information on the genetic control of grain colour in *Panicum miliacem* following crosses between forms with white, brown, gray, red and cream coloured grain. He found possibility for recessive gene to accumulate in the genotypes, for multicoloured forms to occur without segregation and for changes in dominance and segregation to arise. He also noted that the reproductive behaviour of the species give rise to positive transgresive segregates for yield, kernel brightness and carotenoid content, some of which have been used in breeding widely grown Soviet varieties.

Bhattacharya and Bhattacharya (2000) observed the inheritance of seed coat colour of *Pisum sativum* L. and *Pisum arvense* L. He studied. The analysis has indicated that six genes (AABBCCDDKKRR) of which two (A and B) had inhibitory effect and two others (K and R) which are mutator in nature were involved. The mutator genes (K and R) had differential action on C and D in presence of the genes with inhibitory effect i.e. A and B. The two genes (A and B) which are responsible for the flower and the stipule base/leaf base colour in *Pisum* were also responsible for the seed coat colour and the other two genes C and D which are responsible for flower colour were also responsible for the seed coat colour. In order to make the behaviour of the genes clear genotypes have been suggested.

The finger millet shows two distinct type of seed coat colour have been recognized, namely brown and white. Amazingly high amount of protein is coupled with the occurrence of white seed coat colour in finger millet. To understand the genetic basis of inheritance of seed coat colour a study was conducted by (Gurunathan, *et al.*) The parent CO 9 (white type) and TNAU 946 (brown type) were selected for crossing during kharif. The F_1 seed were brown seed coat colour this shows the brown seed coat colour is dominant over white seed coat colour. F_2 population consists of 164 plants. Among them, 159 plant produced brown seed coat colour and 5 plants were produced white seed coat colour.

2.2 Mean performance and variability

The possibility of improvement in any crop is directly related to the variability present in crop population. It is a basic requirement for any breeding programme for improving the character(s) and/or cultivar performance. The genetic variability in a population is primarily due to the differences in genotypic composition of individuals for a particular character. However, phenotypic variation includes both genotypic as well as environmental component.

Abraham *et al.* (1989) grew twenty diverse genotypes of finger millet at Shilong during *kharif.* Phenotypic and genotypic coefficients of variation were high for effective tillers per plant, grain yield per plant, 1000 grain weight and fingers per ear. Broad sense heritability was high for day to maturity (99.5%), days to flowering (97.7%), fingers per ear (83.3%) and 1000 grain weight (98.1%).

Sharma *et al.* (1996) studied the productivity related traits in 40 genotypes of ragi for genetic variability and performed component analysis. Him Ragi 20, Him Ragi 23, GE-624 and GE-2675 were high yielder. Phenotypic coefficients of variability were found to be slightly higher than the corresponding genotypic coefficient of variability.

Sankara *et al.* (1998) observed genetic variability and density for protein and calcium content in finger millet in relation to grain colour. Thirty-six genotypes with varying seed colour revealed that white seeded genotypes had higher protein content while brown seeded genotypes showed wide range of values. Genotypic coefficient of variability was moderate and high for protein and calcium, respectively.

Mnyenyembe and Gupta (1998) observed the variations among 196 accessions of finger millet at Chitedae and Makoka research stations during the 1998-99 rainy season. The differences between germplasm accessions for number of days to flowering, plant height, finger length, finger width, number of fingers, number of productive tillers, panicle yield, and grain yield were observed.

Seed protein, iron and calcium contents showed high estimates of genotypic coefficients of variability in 57 genotypes evaluated for nutritional quality parameters by Maloo *et al.* (1998). They concluded that additive gene effects, which can be improved through artificial selection, largely govern such traits.

Ravisankar *et al.* (2000) evaluated sixteen promising finger millet lines for yield contributing characters. The lines PR 202 x GE 1409 -1-6 and PR 202 x GE 1409-2-5 were significantly superior in terms of number of fingers per head, grain weight per head and ear head weight and matured in 101 and 100 days after planting respectively. The cultivar MR -6-7-3 was superior in terms of number of fingers per ear head, ear head weight, grain weight per ear, ear length and matured in 114 days after planting. However, another line, MR 23-11-5 was significantly superior in terms of number of fingers per head, ear head weight and grain weight per head. However, 1000 grain weight was similar in all three maturity groups. The authors concluded that the maturity of the cultivars prolongs corresponding yield contributing characters which also influence the increase in yield.

Bendale *et al.* (2002) studied genetic variability of 14 quantitative characters using 29 diverse genotypes, of finger millet. High phenotypic and genotypic coefficient of variability were recorded for number of tillers, number of effective tillers, grain yield per plant, straw yield per plant and weight of grains of main ear head.

Genetic variability was studied in 178 genotypes of finger millet for fifteen quantitative characters by Satish *et al.* (2004). Significant difference among the genotypes was recorded for all the characters. The estimates of genotypic variances showed a considerable range of variation for most of characters. High heritability coupled with the high genetic advance as percent of mean was observed for number of tillers, productive tillers, days to 50 per cent flowering, fingers number per ear, length of ear head, length of finger, floret number per spikelet, spikelet density, ear weight, test weight, straw yield and grain yield indicating the presence of additive genetic effects for the manifestation of these characters. Plant height, days to maturity and flag leaf length exhibited high heritability with moderate genetic advances which indicate the presence of both additive and non additive genetic effects of these characters.

Shanthakumar and Lohithaswa (2004) evaluated eighteen finger millet genotypes for grain yield and its components under three environments. Variance due to genotypes was significant for all the traits. G X E (linear) component was non significant for all the traits and non linear component was significant for ear length. The genotype KM-225, PPR-2614 and PR-

202 were found to be stable with higher grain yield. The genotype PPR-2614 was also found stable for fodder yield per plant with higher mean.

Ravishankar *et al.* (2004) conducted experiment on eleven stabilized finger millet genotypes of different maturity groups and evaluated them along with standard check varieties for grain and straw yield and as well as reactions to leaf blast, neck blast and finger blast diseases, the long duration genotype MR-33 and medium duration genotypes of KMR-9 and KMR-3 were found significantly superior for higher grain and straw yield, and also showed high resistance to leaf, neck and finger blast. Although the early maturing genotypes KMR-7 and KMR-4 were also found to be significantly superior for grain and straw yield but they showed moderate tolerance to leaf, neck and finger blast.

Roy (1999) determined the magnitude of gene action governing yield and yield component using means of six generation VIZ $P_{1,}$ P_2, F_2, F2, B1 and B_2 of a cross, Maibi X CRM 53. He found that both additive and non additive gene action were important in controlling all the character studied. As for interaction parameter is concerned, dominance X dominance type of gene interaction was important than the additive X additive and additive X dominance for evaluation traits.

Shrikant *et al.* (2000) conducted experiment on sixteen early hybrids of pearl millet and tested them in three environmental (location x year combination) conditions and stability parameters were worked out for days to 50% flowering and yield per plant. The mean squares due to hybrids, environments and hybrid x environment interaction were found to be highly significant for yield per plant and indicated variable response of hybrids under changing environments. However, days to 50% flowering was significant for hybrids but it was non-significant for hybrid x environment interaction, indicating insensibility of early hybrids which could be of great value under fluctuating environmental conditions.

Singh (2005) conducted a experiment comprising of $45F_1$, $45F_2$ and 10 parents laid in a RBD with three replications. Observation were recorded on twelve traits and analysed through diallele cross analysis excluding reciprocals. Dominant alleles were more frequent for most of the traits. Unequal distribution of negative and positive alleles among parents was found for all the traits.

Sanjeevkumar and Singh (2005) observed gene action for yield and its components and some grain quality traits in rice in nine parents F_2 diallele (excluding reciprocals). Five out of the nine parents were semi dwarf (90-155cm) suitable for cultivation in mid and low hills and four were intermediate (115-125cm). Gene action estimated through Hayman's (1954) approach revealed that both the additive and non additive gene actions and observed predominance of non additive gene action for traits such as plant height, days to 50% flowering, days to maturity, leaf area index, panicle length, 100 seed weight and net assimilation rate, while Predominance of additive gene action was found only for amylose content. Only dominant gene action was reported for grain yield, biological yield, harvest index, dry matter, grain length, grain breadth, grain length: breadth ratio and protein content.

Vedprakash (2005) evaluated six generations ($P_{1,}$ P2, F1, F_2, B_1 and B_2) of two crosses namely PBW 373 X RAJ 3077 and RAJ 3777 X RAJ 3077 in RBD for days to heading, flag leaf area grain yield per spike and yield per plant under normal and late sown condition. The data of six generation were subjected to scaling test and joint scaling test to detect epitasis. Additive dominance model was adequate only in cross PBW 373 X RAJ 3077 under normal sown condition for grain yield per plant and in remaining cases epitasis was observed. The predominant role of dominant gene effect was observed for most of traits studied in both the cases.

2.3 Heterosis studies

Lakshmana *et al*. (2004) studied heterosis in twenty F_1 crosses involving four female and five male parents at regional agricultural research station, Bijapur. Thirteen hybrids were exhibited significantly positive heterosis for grain yield over the better parent. The high magnitude of heterosis for grain yield was displayed by 841A X IPC-0094(84.10%), 93111A X IPC487 (83.70%). These crosses also produced high grain yield than the population mean and could be assessed further for exploiting hybrid vigour. In general crosses based on 841A, 93111A, 843A as females, involving IPC0094, IPC-390 and IPC-811 as pollinators were more heterosis.

Silva Junior *et al*. (1987) studied 46 varieties and hybrids of cabbage and observed that hybrids were superior to the Brazillian varieties in yield, quality, uniformity and vigour.

Zeng and Cao (1998) conducted 5 x 5 diallele crosses in non heading Chinese cabbage. They found positive heterosis for plant weight, blade weight, and petiole weight. The negative heterosis for dry weight, crude weight was recorded.

Gurunathan *et al.* (2006) derived 21 F_1 hybrids of finger millet from a 3 x 7 line x tester mating design along with their parents and utilized them to estimate the heterosis for 10 traits including seed yield and quality traits, namely, protein and calcium content. The parent CO (Ra) 14 was used as a standard parent. Based on standard heterosis and perse performance, the superior crosses were identified for each trait. The crosses Indaf 11 x DPI 2011 and CO 9 x PES 400 for grain yield, CO 9 x CO (RA) 14 for protein content and CO 9 x GPU 28 and CO 9 x TRY 1 for calcium content recorded significant standard heterosis, combined with high per se performance.

2.4 Seed quality parameters

2.4.1 Germination studies

Taranenko (1965) reported that sorghum seeds harvested at wax stage gave a germination rate of 90-98 per cent and seed viability of 91-99 per cent.

Oelka *et al*. (1969) obtained higher seed yield as grain moisture decreased from 43 to 31 per cent. The yield increased slowly between 13 to 19 per cent and remained constant there after germination percentage increased steadily as grain moisture decreased. Shoot length of seedlings indicated faster growth as grain moisture decreased to 13 per cent.

Harrington (1973) obtained maximum yield and potential germination in most of crops before their grain moisture content decreased to 30 per cent.

Khan and Hussain (1974) found highest germination from seeds harvested 21 days after flowering and lowest germination from seeds 15 days after flowering of summer crop.

Narayanaswamy and Javaregowda (1986) conducted a field experiment to find out the physiological maturity and germinability in three finger millet varieties. Seed harvested 12 days after 50 per cent flowering were tested for moisture content, 1000 seed weight and germination per cent. Seed moisture revealed a linear correlation with the days after 50 per cent flowering with a regression of 0.98. Short duration variety recorded maximum seed weight and attained 3 days early physiological maturity as compared to long duration. Germination was observed to be increasing with decrease in moisture content. Similar trend was also observed in case of moisture content of seed and dry matter accumulation.

Raghvendra *et al.* (1990) conducted germination test on two verities of finger millet namely Nirmal and KM-13. They found that the temperature of 20˚C and low and high temperature of 20-30˚C were superior in case of both the varieties. While, high constant temperature of 30˚C reduced the germination percentage.

Krisnappa *et al*. (2001) grew eight cultivars (GPU -26, GPU-28, HR-374, HR -94, indaf –8, indaf –9, MR – 1 and PR - 202) of finger millet in

Bangalore to evaluate the seed quality characters. The highest germination percentage was recorded in GPU-26 (86.0%), followed by HR-374 (72.0%), indaf-9 (71.0%), MR (70.0%) and lowest in indaf-8 (23.0%). Fresh ungerminated seed (FUG) was recorded highest in index-8 (25.0%) and lowest in GPU-26 (13.0%). There was a negative relationship between germination percentage and FUG. The highest shoot length (7.50cm), root length (7.55cm), seedling dry weight (2.00mg) and 1000 seed weight (3.55g) were recorded in HR – 911. The lowest shoot length was found in GPU-26. The lowest root length (6.40cm), seedling dry weight (1.65mg), and 1000 seed weight (1.35g) was recorded in HR-374. Vigour index was highest (168.0) in GPU-26 and lowest (30.0) in Indaf-8; electrical conductivity of seed was lowest (116.0 micro sm^{-1}) in HR-97 and highest (300.7 micro sm^{-1}) in MR-1

Joshi *et al.* (2003) presoaked the seeds of pearl millet hybrid GHB-30 with distilled water (DW), gibberellin (GA_3) and kinetin (Kn). The treated seeds along with untreated (control) were kept for germination in saline medium ranging from 0 to 12mmhos/cm. There was a decline in germination index (GI) and root as well as shoot growth with increasing salinity levels. Nevertheless, among treatments GA_3 treated seeds exhibited the highest shoot growth and Kn treated seeds showed the highest root growth and GI.

The possibility of seed invigoration by PGRs for germination under saline conditions was also by the authors explored.

Maiti *et al.* (2006) estimated the present review, recent trends on research on maize seeds and seedling establishment are discussed in brief. Several studies are on the biochemistry and biotechnology of maize seeds such as Vp1-mediated repression of alpha-amylase genes, hexose phosphorylation at distinct cellular sites, characterization of thiamine-binding proteins, a transcript encoding a nucleic acid-binding protein, etc. The paper discusses various factors affecting seed viability, biochemistry of germination and seedling development, emergence, photomorphogenesis, seedling establishment such as fungal infection, accelerated ageing, water stress, salinity, cold tolerance, its mechanism and various other factors. The concerted studies need to be undertaken on the genotypic variability of maize cultivars for various seed and seedling establishment traits and their adaptations to various stress factors and in understanding the mechanism of tolerance to these stress factors.

2.4.2 Seed vigour and viability

Heydecker (1969) reported that low vigour seeds undergo rapid deterioration in storage which results in delayed germination, increased susceptibility to micro organisms and reduced seedling growth rate and seed yield.

Parry (1976) reported that seedling vigour is inter- related to speed of germination, seedling growth rate and performance in the field with respect to seedling emergence, plant growth and yield.

Khanna and Yadav (1979) observed quick decline in viability when seed moisture exceeded 14 per cent and stored at 75-90 per cent relative humidity. The seeds of wheat and maize showed comparable fall in germination while the seeds of bajra showed maximum germination, barley was considerably safe and significant drop in germination could be observed only after 60 days at 90 per cent relative humidity.

Generally maximum seed viability and vigour is seen at the time of physiological maturity (Singh and Borikar, 1985; Roberts and Ellis, 1980). After attaining physiological maturity seed begin to deteriorate on the mother plant and proceed at varying rate depending on several factors such as pre and post maturation, environmental, pathological, seed moisture content, method of harvesting , threshing, drying and storage condition.

Agarwal and Kharlukhi (1985) stated that seed leachates were highest from seed stored at high temperature and relative humidity loss of seed vigour and viability was less in green grass followed by chick pea and wheat.

Kumar and Dev (1990) studied the storage behaviour of rice under ambient condition and reported that seeds produced during the rainy season had a higher storage life than the seeds produced in winter. Red grain variety generally extended high storability.

Paniya *et al.* (1997) in an analysis of 47 genotypes of pea recorded that there was significant variations for all vigour parameters. Seed vigour showed significant association with TZ test (0.38). Speed of germination was found significantly associated with standard germination percentage (0.36) and seedling length (0.32).

The investigation conducted by Katna *et al.* (2002) on maize line reported significant differences for mean of all traits viz. germination percentage, seed vigour index and field emergence. Similar observations were reported by Mazur (1994) as he observed high variability at seedling emergence from seed having variable shape, size and sowing dates.

In a study to evaluate crop establishment and seedling vigour of 205 genotypes of introduced form ICRISAT India, Maiti *et al.* (2002) observed significant differences among genotypes. Genotype A 13 selected for having highest number of leaves and high vigour. The genotypes having maximum dry matter were C 112 and B 172.

2.5 Studies related to different generations

Grain yield and number of ears per plant showed high value of heritability and genetic advance on data derived on yield from 23 accessions of *E. coracana* (Verma, 1989). This suggested that selection of these traits by phenotype should be effective.

Ramaswamy *et al*. (1991) estimated broad sense heritability in four genotypes for six yield components. High heritability and genetic advance were observed for green fodder yield and number of leaves per plant.

Seed yield per plant (59-124%), days to flowering (180 and 17%), plant height (56 and13%) and days to maturity (49 and 29%) showed high heritability and genetic advance (percentage of mean) on 90 lines of *E. coracana* as evaluated by Thakur *et al.* (1995).

Mnyenyembe and Gupta (1998) observed variations among 196 germplasm accessions of finger millet from Malawi studied at, Chitedze and Makoka Research Stations during the 1988/89 rainy season. The differences between germplasm accessions for number of days to flowering, plant height, finger length, finger width, number of fingers, and number of productive tillers, panicle yield, grain yield, and finger blast incidence were significant at both locations. Six germplasm accessions with highest values and six accessions with lowest values of each trait are listed.

Gupta (1999) studied the inheritance of genetic male sterility. INFM 95001 was crossed with male-fertile line (IE 3318) and three unrelated male fertile line (FMV 1, FMV 2 and SDFM 957). All the F_1 plants derived from these four crosses were male fertile. Chi square test for segregation for male fertile and male sterile plant in F_2 and test cross generation indicated that male sterility in these crosses of finger millet is controlled by one major recessive gene. The gene symbol ms_1ms_1 is proposed for this gene in INFM 95001.

Sakhare *et al.* (2002**)** studied a 9 x 9 diallel excluding reciprocals made in gamma rays treated and untreated genetically divergent varieties of durum wheat. Genetic components and graphic analysis were worked out for plant height and ear length in F_1 untreated, F_1 treated, F_2 untreated and F_2 treated populations. Both component and graphic analysis revealed the importance of both additive and non-additive type of gene action for controlling both the characters studied in all the populations. The additive components are usually decreased in treated F_1 as well as F_2 populations for both the characters, while non-additive components were relatively increased in treated populations than untreated ones for both the characters studied. The graphic analysis revealed that the array points were comparatively more scattered in gamma rays treated populations, indicating the creation of new genetic variability in these populations. Under these situations for exploitation of both additive and non-additive genetic variance and also for broad base adapted varieties, in certain elite crosses, population breeding approach in the form of biparental mating between selected recombinants as well as mating of selected segregants between crosses in early segregating generations should be practiced.

Anantharaju and Meenakshiganesan (2005) observed correlation and performed path coefficient analysis among 50 genotypes of finger millet. The grain yield showed positive and significant genotypic correlation with number of productive tillers and culm thickness. Number of productive tillers had high positive direct effect and culm thickness and number of leaves had moderate direct effect on grain yield. Finger length had high indirect effect on grain yield through number of leaves and days to 50% flowering.

Kumar, *et al.* (2006) observed that genetic variability is essential for selection thereby improving yield. They determined the extent of variability, GCV, PCV, heritability and genetic advance for 12 characters in 50 S 1 lines of a maize population. Highly significant differences among the lines were observed for all the characters. Highest genotypic and phenotypic coefficient of variation was observed for anthesis silking interval followed by yield per plot, while it was lowest for ear diameter. The heritability estimates were invariably high for all the characters. Genetic advance as per cent of mean along with heritability was considerably high for days to 50% tasseling, days to 50% silking, anthesis silking interval and yield per plot indicating that selection could be effective for improving these traits including yield.

2.6 Characters association

Prabhakar and Prasad (1983) obtained significant positive correlation of 1000 grain weight with grain yield in 20 diverse genotypes of finger millet.

Sen and Hamid (1986) studied simple correlation between seed yield/plant and seven other characters in 107 samples of *P. miliaceum*. Seed yield/plant was positively associated with days to flowering, plant height, tiller per plant and panicle length. Straw weight was positively correlated with days to flowering, plant height and panicle length and negatively correlated with number of tillers per plant. Plant height was strongly associated with days to maturity and panicle length.

Jiban *et al.* (1998) studied correlation on green fodder yield and its components in 13 diverse genotypes of pearl millet. Green fodder yield per plant was significantly and positively correlated with number of tillers per plant, number of leaves per plant, leaf weight, stem weight, dry matter and plant height. Similarly there were significant and positive correlation among number of tillers per plant, leaves per plant, leaf weight in all combinations.

Bandyopadhyay (1998) studied variability, heritability and correlation among seven quantitative characters of 29 finger millet genotypes under rainfed conditions. Significant differences were observed for characters. Higher estimates of heritability, GCV and genetic advance were registered in grain yield. It was assumed that grain yield was controlled under additive gene effect. Days to 50 per cent seedling, number of productive tillers, number of fingers per head and days to maturity showed non-additive gene affects, except days to maturity, other characters registered non-significant correlation with grain yield. Days to maturity indicated that it is the most prominent character determining grain yield in ragi at higher elevations of hill.

Gollagi and Chetti (2006). Studied 12 genotypes of little millet (*Panicum miliare* L.) to know the relationship of various morpho-physiological traits with grain yield and compared them with local check.

Considerable variability was found for all the characters studied. The plant height, number of green leaves, number of tillers, leaf area, days to 50% flowering, days to physiological maturity, leaf dry weight, stem dry weight, ear dry weight, number of grains per plant, 1000-grain weight and harvest index were found to vary significantly. The genotypes TNAU-63, OLM-20, TNAU-89 and CO-2 recorded higher yields compared to all other genotypes. Correlation also indicated close association of these parameters with the grain yield.

Yield and yield components were studied by Basheeruddin and Hussainsahib (2004) in 15 foxtail millet varieties for genetic variability, heritability and character association. Grain yield exhibited the highest coefficient of variability followed by number of tillers per plant. Days to 50% flowering had the highest heritability. The high amount of heritability coupled with high genetic advance indicated additive gene action to be in operation for all the characters under study. However, none of the characters showed significantly positive correlation with grain yield.

MATERIALS AND METHODS

The present investigation was carried out during *Kharif*, 2006 at the experimental farm and seed testing laboratory of Department of Seed Science and Technology, G. B. Pant University of Agriculture and Technology, Hill Campus, Ranichauri, District Tehri Garhwal, Uttarakhand. The details of materials used and procedures followed during the course of investigation are described in this chapter.

3.1 Experimental site

3.1.1 Location

The experimental site at Hill Campus, Ranichauri is located at 10 Kms away from Chamba (Reshikesh – Gangotri Road) at an altitude of about 2000 meters above mean sea level, lying between $30^0$15’ N latitude and 78^0 30’ E longitudes under mid hill zones of Uttarakhand, India. The laboratory tests and evaluation of seeds were conducted in the Laboratory of Seed Science and Technology.

3.1.2 Climate

The climate of Ranichauri is humid temperate. The mean monthly minimum and maximum temperature varies between 2.2^0C to 16.9^0C and 12.0^0C to 24.6^0C, respectively. Average rainfall of 1178.4 mm is experienced annually. Monsoon arrives in second fortnight of June and ends in September. However, drizzling continues up to first week of October. Major portion of annual rainfall (about 61%) is received during the monsoon. The winter rains and snowfall occur during December-February and hailstorms are frequent from first week of April to 15th May. Winter is very severe and light to heavy snowfall is a regular feature of Hill area and summer is mild. Detailed meteorological data recorded for different parameters during the cropping period is presented in Annexure I.

3.1.3 Soil

The soil of the experimental block was silty clay to silty clay loam in texture, low in available nitrogen (210.0 to 218.5 kg/ha) and available phosphorus (11.5 to 13.5 kg/ha) and rich in available potash (408 – 418 kg/ha). The pH of the soil varied from 5.5 to 5.6, electrical conductivity as measured in 1:2 soil water ratio was 0.5 to 0.7 dsm $^{-1}$. The depth of soil extends up to 2.0 meter (Annual Report, 1997-98, AICRP on Small Millets).

A mixture of soil, compost (2:1), and 100gm fertilizer (15:15:15) is made and added in to 14 plastic pots, for pot culture experiments.

3.1.4 Cropping history of the experimental field

The experimental field, which is situated in the Seed Science and Technology block, had a good fertility level. Vegetable pea was cultivated in the experimental field during the previous cropping season.

3.2 Experimental material

The experimental material for present investigation comprised of seven generations and two parents (Gaja local and INFM 95001Male sterile). The material used in the study was received from Department of Genetics and Plant Breeding, College of Forestry and Hill Agriculture, Hill Campus, Ranichauri.

Table 3.1 Meteorological data during the course of investigation

Month	Temperature (°C)		Rainfall (mm)	Relative Humidity (%)	Wind Speed (K/hr)
	Max	Min			
June	25.6	15.2	107.1	68.0	4.7
July	23.5	17.4	289.5	86.5	4.6
Aug	23.7	16.6	166.3	88.0	4.2
Sept	22.9	14.7	50.4	85.0	5.1
Oct	21.1	10.3	42.5	77.0	4.7
Nov	17.5	6.0	3.4	75.0	5.0
Dec	14.4	3.4	55.0	67.5	4.5

3.3 Experimental details

Seven generations of finger millet seeds with distinct characteristics, were taken as treatments in the proposed study. The characteristics feature of Gaja local (male parent) and INFM 95001 (male sterile parent) are given below.

3.3.1 Gaja local

Gaja local line is used as male parent has around 160 days plant duration. Plant shows loose fingers and plant height about 125-135cm.

3.3.2 INFM 95001

The male sterile line is homozygous for the simply inherited recessive ms_1 gene. It has retained full male sterile in different environments. Male sterile plants produced fully fertile F_1 progeny when pollinated by any fertile homozygous parent.

Seeds are round and white at physiological maturity. Individual grain mass is heavier in male sterile (3.5 mg) than in male fertile plants (3.0mg). Seed dormancy is present for 3 or 4 weeks after harvest.

3.3.3 Experimental design and layout plan

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. Each of the generation was sown in three continuous rows manually. The replications were located in single terraces. The details about the experiment lay-out are given below:

Experimental Design	: Randomized Complete Block Design
Number of treatments	: seven generations and two parents
Number of replications	: 03
Number of plants per row	: 25
Spacing	: 25 X10 (cm)
Date of sowing	: 27-06-06
Date of harvesting	: 26-11-06 to 29-12-06

3.3.4 Field preparation and layout

The field was prepared by ploughing with power tiller twice up to a depth of 20 cm. Thereafter leveling was done. The field was fertilized with 24 kg N and 60 kg P_20_5 per ha through DAP. All fertilizers were applied as basal before sowing.

3.3.5 Seed sowing

The seeds were sown on 27-6-2006 at about 3-4 cm depth by opening furrow with kutla. Sowing was done in two rows in 25 cm apart. Plant to plant spacing was maintained as 10cm. Each furrow was manually dribbled with seed and covered with soil immediately.

The seed were also sown on same date in all 14 plastic pots. 10 seeds were sown in each pot and watered.

3.3.6 Crop management

The crop was raised under rainfed condition. The distribution of rainfall was fairly good throughout the crop season. Thinning was conducted at 20 days after sowing. Two hand weedings were done at 30 and 50 DAS to keep the experimental plots free from weeds.

In case a pot watering is done once in two days throughout the crop season. The pot plants were thinned and retained 5-6 plants per pot and weeds were removed by hand.

3.4 Details of field observations

The field and laboratory observations were recorded in three randomly selected plants in each replications and treatments for recording following observations.

3.4.1 Morphological characters

Ear shape

Seed coat colour

3.4.2 Quantitative characters

Plant height (cm)

Number of leaves per plant

Flag leaf length (cm)

Flag leaf width (cm)

Days to 50% flowering

Number of tillers per plant

Number of fingers per ear

Number of grains per finger

Finger length (cm)

Finger width (cm)

Days to maturity

Grain yield per Ear head (g)

3.4.3 Seed quality parameters

1000 seed weight (g)

Germination test (%)

Viability test (%)

Seedling length (cm)

Root length (cm)

Shoot length (cm)

Seedling Fresh Weight (g)

Seedling Dry Weight (g)

Vigor index I

Vigor index II

3.4.1 Morphological characters

3.4.1.1 Ear shape

Shape of ears of different lines was categorized as open, semi compact and compact type. Rating of the three types was done as 1, 2 and 3 respectively to facilitate easy evaluation.

3.4.1.2 Seed colour

The seed coat colour of different generations was almost similar to each other. However very low variation that was recorded and placed under rating as A, B, C and D with different numbers by using RHS colour chart.

3.4.2 Quantitative characters

3.4.2.1 Plant height

Plant height was recorded at 30 days, 60days and at maturity stage. For this purpose the height of three randomly selected plants were measured by scale from the ground level to tip of the top most ear head. The average was expressed as plant height in cm.

3.4.2.2 Flag leaf length

Flag leaf length of three plants were measured in cm .The length of flag leaf on main tillers was measured from ligule’s of leaf tip at flowering stage

3.4.2.3 Flag leaf width

Flag leaf width of three plants was measured in cm. The width of flag leaf was measured from the centre of leaf length at flowering stage.

3.4.2.4 Days to 50% flowering

The number of days required to initiation of 50% flowering was recorded in each replications and treatments.

3.4.2.5 Number of tillers per plant

Total numbers of basal tillers per plant were counted from each replications and treatments at flowering stage.

3.4.2.6 Number of fingers per ear

Total number of the fingers present on the main ear at dough stage is calculated on individual ear head randomly in three plants in each replication.

3.4.2.7 Number of grains per finger

Total number of grains per finger was counted from the middle portion of the thumb finger on main ear at dough stage.

3.4.2.8 Finger length

The length of the longest finger on the main ear was measured from the base to tip of the finger at dough stage from the three randomly selected plants from each replication.

3.4.2.9 Finger width

The finger width measured across the centre of longest finger at dough stage from three randomly selected plants from each replication.

3.4.2.10 Days to maturity

Number of days taken for crop maturity was taken as the number of days from sowing to the maturity of crop.

3.4.2.11 Grain yield per ear head

The total grain yield per ear head was obtained from the three tagged plants in each replication and was averaged. The total number of grains obtained from a single ear head was multiplied with number ear head per plant and single grain weight to derive grain yield per plant.

3.4.3 Seed quality parameters

3.4.3.1 1000 Seed weight (g)

After threshing, seeds were dried and random samples of 1000 seeds were counted from each replication and weight was recorded on electrical balance.

3.4.3.2 Germination test

Three pieces of circular filter paper were placed in a petriplate. The filter paper was moistened with water and 50 seeds were arranged on top of the moist blotter as per the procedure of ISTA (ISTA, 1996). The closed petriplate was placed in a germinator at 25 ± 1^0 C for 7 days. The seedlings were evaluated at regular interval and normal seedlings were counted on 7^{th} day. Germination per cent was calculated as formula given below.

Germination per cent = normal seedlings /total number of seed X 100

3.4.3.3 Seedling length (cm)

Five seedlings in each replications were randomly selected for measurement of root and shoot length on the day of final count and the mean length is expressed in centimeter.

3.4.3.4 Shoot length (cm)

The shoot length was measured with the help of a measuring scale for ten randomly selected seedlings on final count after 7 days in each replications.

3.4.3.5 Root length (cm)

The root length was measured with the help of a measuring scale for ten randomly selected seedlings on final count after 7 days in each replication.

3.4.3.6 Seedling fresh weight (g)

Seedling fresh weight was assessed after the final count in the standard germination test (7days). Five normal seedlings were randomly taken from each replication of germination test. The fresh seedlings were weighed and the average seedling fresh weight was calculated.

3.4.3.7 Seedling dry weight (g)

The fresh weighed seedling was dried in an oven for 72 hrs at 72^{o}C temperature. The dried seedlings were weighed and the average seedling dry weight was calculated

3.4.3.8 Vigor index

The seedling vigour index was calculated by two different methods (Abdul Baki and Anderson, 1973)

Vigor index I

Seedling vigour index I = Standard germination % X Seedling length (cm)

Vigor index II

Seedling vigour index I =Standard germination% X Seedling dry weight (gm).

4.5 Statistical Analysis

The analysis of variance (ANOVA) was carried out as explained by Corchran and Cox (1959).

Source of variance	**Degree of freedom(df)**	**Sum of square**	**Mean sum of square**	**Variance ratio (f valve)**
Replication (r)	r-1	Sr	Sr / r-1 = Mv	Mr / Me
Treatment (t)	t-1	St	St / t-1 = Mt	Mt / me
Error(e)	(r-1)(t-1)	Se	Se / (r-1)(t-1) = Me	

The data obtained during the course of investigation were analyzed by using standard statistical procedure for Randomized Complete Block Design. Coefficient of variation (CV %) and Standard error of means

(SEm±) were computed in each case at critical difference (CD) at 5 per cent level of significant effects (Panse and Sukhatme, 1954).

4.5.1 Heterosis and Heterobeltosis

The heterosis of each character was calculated as percentage of superiority of F_1 hybrids over the better parent and mid parent as determined by Hayes *et al*. (1956).

a. mid parent heterosis = $\frac{F_1 - MP}{MP} \times 100$

b. Better parent heterosis = $\frac{F_1 - BP}{BP} \times 100$

Where F_1 is the mean of F_1 hybrids and MP is the mean of two parents involved the cross and BP is the mean of better parent.

4.5.2 Correlation analysis

Simple correlation coefficient (r) was worked out (Panse and Sukhatme, 1954) to determine the correlation between morphological, physiological and seed quality parameters. Simple linear correlation coefficient (r) was calculated using the formula given below-

$$r = \frac{\sigma x . y}{\sigma x . \sigma y}$$

Where

r = Correlation coefficient

σ x y = Covariance between x and y

σ x = Standard deviation of x

σ y = Standard deviation of y

EXPERIMENTAL RESULTS

Present investigation entitled "studies on seed quality parameter in different generations of finger millet (*E.coracana* (L) Gaertn) was carried out on seven generations of finger millet in the experimental farm, Department of Seed Science and Technology, Hill Campus, Ranichauri. The result obtained for various morphological, physiological and seed quality characters are being presented under the following heads.

4.1 Qualitative parameters

4.2 Mean performance of generations

4.2.1 Field parameters

4.2.2 Seed quality parameters

4.3 Estimation of heterosis and heterobeltosis

4.4 Correlation coefficient

4.4.1 Field parameters

4.4.2 Seed quality parameters

4.1 Qualitative Characters

The results of various qualitative traits scored for different generations are presented below:

4.1.1. Ear shape

Visually examined variation observed in ears shape was of three types: open type (1), semi compact (2) and compact type (3).

Open type had straight, elongated and slender fingers, compact types had fully incurved and short, while semi compact showed a finger types slightly incurved and of mid-range of two types. A gradation is among all accession is presented in Table 4.1

4.1.2. Seed colour

The colour of seeds for eight generations and two parents were recorded an array of variants of red brown colour types. The seeds have been designated as A, B, C, and D depending upon intensity of red brown colour (as in colour chart). The variation observed in eight generation and two parents are recorded in Table 4.1 and annexure II.

4.2 Mean performance of generations

The analysis of variance for all the characters is given in annexure III and IV. The differences among the generation were found significant for all the character except few characters under study. The significant differences among the generation indicate the existence of good deal of variability with respect to various quantitative traits, which have been described below. The mean values of eight generation and two parents with respect to different quantitative characters have been presented in Table 4.2, 4.3 and 4.4.

During the course of study, information obtained on mean and the extent of variability, have been discussed under the following heads and sub heads:

4.2.1 Field parameters

4.2.1.1. Plant height (30 Days)

The range of plant height was found to be 41.77 to 53.70cm. The plant height was observed maximum (53.70cm) in Gaja local followed by F_2 generation (50.33cm) and F_5 generation (49.60cm), whereas minimum plant height (41.77cm) was observed in F_6 generation. The over all mean for this character was 46.75cm (Table 4.2).

Table: 4.1 Morphological characters

S.No	Generations	Ear shape	Seed colour number	Seed colour
1	F_1	3	166C	Squirrel brown,
2	F_2	3	Mixed	Golden buff, Squirrel brown, Tuscan yellow
3	F_3	2	165D	Yellow ohcre
4	F_4	2	164D	Champagne
5	F_5	3	165B	Almond shell
6	F_6	2	164B	Golden buff
7	F_7	2	164B	Golden buff
8	F_8	-	165C	Cinnamon
9	Gaja local	1	166C	Squirrel brown
10	INFM 95001	2	162C	Tuscan yellow

4.2.1.2. Plant height (60 Days)

From the analysis of variance (annexure III), this character was found to be highly significant. The plant height at 60 days after sowing showed the range of variability from 81.03 to 109.2cm. The plant height was observed maximum (109.2cm) in Gaja local followed by F_5 generation (105.8cm) and F_8 generation (105.6cm), whereas minimum plant height (81.03cm) was observed in F_7 generation. The over all mean for this character was 98.93cm.

4.2.1.3. Plant height (at maturity)

Plant height at maturity showed the range of variability from 114.6 to 123.4cm. The plant height was observed maximum (123.4cm) in INFM 95001 followed by F_4 generation (121.7cm) and F_2 generation (120.9cm), whereas minimum plant height (114.6cm) was observed in F_7 generation. The over all mean for this character was 119.0cm (Table 4.2).

4.2.1.4. Number of leaves per plant

From the analysis of variation (annexure III), this character was showed highly significant. The maximum numbers of leaves per plant (14.00) were recorded for INFM 95001 line, while the minimum number of leaves per plant (9.66) were observed in F_4 and F_5 generation over all mean of the character was 10.77.

4.2.1.5. Flag leaf length

Flag leaf length varied from 26.00 to 36.13cm. The flag leaf length was observed highest (36.13cm) in F_4 generation followed by INFM 95001 line (34.33cm) and F_2 generation (33.93cm), however the lowest flag leaf length (26.00) was observed in F_7 generation. The over all mean for this character was 32.26cm (Table 4.2).

4.2.1.6. Flag leaf width

Flag leaf width showed variability from 0.967 to 1.33cm. The flag leaf width was observed highest (1.33cm) in F_4 generation followed by INFM 95001 line (1.103cm) and F_7 generation (1.100cm), while the lowest flag leaf width (0.967cm) was recorded in F_5 and F_6 generations. The over all mean for this character was 1.025cm.

4.2.1.7. Days to 50 per cent flowering

Days taken for 50 per cent flowering ranged from 103.0 to 125.6 days with over all mean were 108.21 by the generations. The maximum (125.6) days for 50 per cent flowering was taken by INFM 95001 line, while minimum (103.0) was observed in F_7 generation. From the analysis of variance (annexure III) shows that days to 50% flowering was highly significant.

4.2.1.8. Number of tillers per plant

The analysis of variance (annexure III) for this character is highly significant. The range for number of basal tillers per plant varied from 2.00 to 4.00. The number of basal tillers per plant were recorded highest (4.00) in INFM 95001 followed by Gaja local (3.667) and F_6 generation (3.00), while lowest (2.00) was observed in F_7 generation. The over all mean for this character was 2.791.

4.2.1.9. Number of fingers per ear

The range for number of finger per ear varied from 5.66 to 7.66. The number of fingers per ear recorded highest (7.66) in INFM 95001 line followed by F_3 (7.00), while least (5.66) was observed in Gaja local. The over all mean for this character was 6.708.

4.2.1.10. Number of grains per finger

Number of grains per finger exhibited variation ranging from 34.67 to 300.7 respectively. The INFM 95001 exhibited minimum number of grains (34.67) in a finger; while highest value for this character was reported in F_1 generation (300.7) followed by F_2 generation (283.0) and F_3 generation (274.3). The over all mean for this character was 220.0. The Table 4.2 shows that the number of grain per finger was highly significant.

4.2.1.11. Finger length

From the analysis of variance (annexure III), finger length was found to be highly significant. The maximum finger length (9.16cm) was recorded in Gaja local followed by F_3 generation (7.93cm). The minimum finger length (5.10cm) was recorded in F_7 generation. The over all mean of the population was recorded 7.10cm.

4.2.1.12. Finger width

For finger width the limit of range varied from 0.86 to 1.73cm. The F_6 generation exhibited minimum finger width (0.86cm) followed by F_7 generation (1.00cm) and F_5 generation (1.20cm), while highest finger width was observed in F_2 generation (1.77cm). The over all mean of the population was recorded 1.28cm. The analysis of variance (annexure III), finger width was highly significant.

4.2.1.13. Days to maturity

From the analysis of variance (annexure III), this character was found to be highly significant. The range for days to maturity varied from 143.7 to 178.0 days with mean of 150.03 days. Days to maturity was observed maximum (178.0) in INFM 95001 MS line followed by Gaja local (149.3 days), whereas minimum days to maturity (143.3 days) were taken by F_7 generation.

4.2.1.14. Grain yield per Ear head (g)

Grain yield per Ear head showed the range of variability from 1.18 to 7.47g. The highest seed yield per plant (7.47g) was observed in F_2 generation followed by F_3 generation (7.37g) and F_4 generation (6.90g), while it was lowest in INFM 95001 MS line (1.18g). The overall mean for

Table 4.2 Mean values of field parameters in Finger millet generations.

Treatment	Plant height (cm)30 Days.	Plant height (cm)60 Days	Plant height at maturity (cm)	Number of leaves per plant	Flag leaf length (cm)	Flag leaf width (cm)	Day's to 50% flowering	Tillers /plant	Ear bearing tillers/ plant	Number of finger/ Ear	Number of grain/ Finger	Finger length (cm)	Finger width (cm)	Grain yield (g)	Day's to maturity
F_2	50.33	101.10	120.90	10.67	33.93	1.033	109.0	2.333	1.333	6.667	300.7	7.133	1.733	7.473	149.0
F_3	43.17	97.83	117.00	10.00	33.47	0.967	104.0	2.333	1.667	7.000	283.0	7.933	1.533	7.373	146.3
F_4	43.87	101.10	121.70	9.66	36.13	1.133	103.7	2.667	1.333	7.000	274.3	7.533	1.333	6.906	145.3
F_5	49.60	105.80	117.70	9.66	30.77	0.967	104.0	2.333	1.667	6.667	241.7	6.733	1.200	5.631	144.0
F_6	41.77	89.83	120.50	10.67	31.60	0.967	104.7	3.000	1.333	6.333	199.0	5.600	0.866	3.164	144.7
F_7	42.83	81.03	114.60	10.67	26.00	1.100	103.0	2.000	1.000	6.667	207.7	5.100	1.000	4.026	143.7
Gaja local	53.70	109.20	120.20	10.33	31.90	0.933	109.0	3.667	2.667	5.667	219.0	9.167	1.167	3.859	149.3
INFM 95001	48.73	105.60	123.40	14.00	34.30	1.103	125.6	4.000	3.000	7.667	34.67	7.667	1.233	1.182	178.0
G. M.	46.75	98.936	119.50	10.70	32.26	1.025	108.21	2.791	1.75	6.708	220.00	7.108	1.258	4.951	150.03
S.Em±	1.9861	4.5168	4.2689	0.9364	3.1765	0.11784	1.5520	0.6267	0.57735	0.91721	6.5979	0.6427	0.14044	0.8007	1.9487
CD 5%	4.2597	9.6875	9.1558	2.0085	6.8129	0.25874	3.3287	1.3433	1.2383	1.9672	14.150	1.3786	0.30120	1.7174	4.1796
CV%	9.37	9.44	2.38	13.05	9.47	7.55	6.99	25.48	40.41	8.58	37.96	18.31	22.06	45.77	76.61

this character was 4.95g. The grain yield per ear head was highly significant (Table 4.2).

4.2.2 Seed quality parameters

4.2.2.1. 1000 seed weight

From the analysis of variance (annexure IV), 1000 seed weight was found to be highly significant. The values for test weight ranged from 2.684 to 4.123g. The genotype INFM 95001 line (4.123g) showed highest test weight followed by F_1 generation (4.108g) and F_2 generation (3.965g), whereas lowest (2.684g) was recorded in F_8 generation. The over all mean was 3.538g.

4.2.2.2. Standard germination per cent

Standard germination per cent showed range of variability from 88.33 to 96.67%. The highest germination per cent was recorded in F_8 generation (96.67%) followed by F_7 generation (93.33%), F_6 generation (91.33%) and F_2 generation (90.67%), however lowest was observed in F_4 generation (88.33%). The over all mean for the character was 91.13%. The Table 4.4 shows that the germination percent was highly significant.

4.2.2.3. Viability test

The analysis of variance (annexure IV), viability was found to be highly significant. Viability test showed range of variability from 91.00 to

98.43 %. The maximum viability per cent was observed in F_8 generation (98.43%) followed by F_7 generation (96.70%) and F_6 generation (95.60%), however minimum viability was seen in INFM 95001 line (91.00%).

4.2.2.4. Seedling length

The seedling length showed the range of variability 12.27 to 13.05 cm. The highest seedling length was recorded in F_1 generation (13.05cm) followed by F_2 generation (12.77cm) and F_6 generation (12.65), whereas lowest was observed in F_4 generation (12.27cm). The over all mean for this character was 12.52cm.

4.2.2.5. Root length

Root length showed the range of variability from 6.06cm to 6.717cm. The mean value for root length was observed highest in F_1 generation (6.71cm) followed by F_6 generation (6.57cm) and INFM 95001 line (6.49cm) for root length, while lowest was in Gaja local line (6.06cm). The over all mean for the character was 6.325cm (Table 4.3).

4.2.2.6. Shoot length

Shoot length ranged from 6.03cm to 6.33cm with over all mean 4.70cm. The maximum shoot length was recorded for F_1 generation (6.33cm) followed by F_2 generation (6.32cm) and F_3 generation (6.19cm), while minimum was in F_7.generation (6.013cm). The over all mean for shoot length was 6.135cm.

4.2.2.7. Seedling fresh weight

From the analysis of variance (annexure IV), this character was found to be highly significant. The values for fresh seedling weight ranged from 0.1120 to 0.172g. The highest fresh seedling weight was recorded for INFM 95001 line (0.172g), followed by F_8 generation (0.168g) and F_1 generation (0.160g), however minimum was observed in F_4 generation (0.1120g). The over all mean for seedling fresh weight was 0.145g.

4.2.2.8. Seedling dry weight

The values for dry seedling weight ranged from 0.0080 to 0.0163g. The highest dry seedling weight was recorded for F_3 generation (0.0163g), followed by F_6 generation (0.0123g) together with F_1 generation (0.0123g), however minimum was observed in F_4 generation (0.0080g). The over all mean for seedling dry weight was 0.0113g. From the analysis of variance (annexure IV) shows that seedling dry weight was highly significant.

4.2.2.9. Seedling moisture content

Seedling moisture per cent showed range of variability from 84.35 to 94.35%. The highest seedling moisture per cent was recorded in F_7 generation (94.35%) followed by Gaja local (93.29%), INFM 95001 line

(93.19%) and F_4 generation (92.86%), however lowest was observed in F_3 generation (84.33%). The over all mean for the character was 91.83%.

4.2.2.10. Vigour index I

From the analysis of variance (annexure IV), vigour index I was found to be highly significant. The seedling vigour index I parameter showed high range from 1083.56 to 1194.36 with over all mean of 1141.11. The generation F_8 generation (1194.36) showed highest seedling vigour index I followed by F_1 generation (1184.66) and F_2 generation (1162.36), however lowest (1083.56) was observed in F_4 generation.

4.2.2.11. Vigour index II

The seedling vigour index II parameter showed range of variability 0.707 to 1.447. The seedling vigour index II was highest in F_3 generation (1.447) followed by F_8 generation (1.160) and F_6 generation (1.128), while lowest (0.707) in F_4 generation. The over all mean for the character was 1.032. From the analysis of variance (annexure IV) shows that vigour index II was highly significant.

4.3 Estimation of heterosis and heterobeltosis

The heterosis was estimated for ten seed quality parameters. The heterosis was calculated by using the mid parent and better parent and these were explained below (table 4.7).

Table 4.3 . Mean values of seed quality parameters in Finger millet generations:

Treatment	Test weight (g)	Seedling fresh weight	Seedling dry weight (g)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Vigour index I.	Vigour index II	Seedling moisture Content (%)
F_1	4.108	0.160	0.0123	6.717	6.333	13.05	1184.66	1.119	92.33
F_2	3.965	0.154	0.0116	6.450	6.320	12.77	1162.36	1.064	91.86
F_3	3.542	0.124	0.0163	6.247	6.193	12.44	1128.51	1.477	84.33
F_4	3.605	0.112	0.0080	6.207	6.063	12.27	1083.56	0.707	92.86
F_5	3.541	0116	0.0100	6.233	6.137	12.37	1100.78	0.891	91.43
F_6	3.512	0.156	0.0123	6.573	6.097	12.65	1151.04	1.128	91.84
F_7	3.042	0.160	0.0090	6.087	6.013	12.43	1161.00	0.839	94.35
F_8	2.684	0.168	0.0120	6.187	6.180	12.36	1194.36	1.160	92.86
Gaja local	3.264	0.135	0.0103	6.063	6.063	12.28	1113.66	0.938	93.29
INFM 95001	4.123	0.172	0.0116	6.493	6.137	12.63	1131.20	1.004	93.16
G.M	3.538	0.145	0.0113	6.325	6.135	12.525	1141.11	1.032	91.83
S.Em+	0.1315	0.02204	0.00157	0.2452	0.1305	0.3528	40.589	0.1395	0.131
CD 5%	0.2744	0.04599	0.00327	0.1158	0.2722	0.73611	84.667	0.2911	0.274
CV%	13.00	312.221	20.04	3.46	1.70	1.98	3.14	20.53	3.01

Table 4.4 mean values of seed viability parameters in different generations.

Generations	Viability test %	Standard germination %
F_1	95.17	90.67
F_2	94.73	91.00
F_3	94.33	90.67
F_4	92.50	88.33
F_5	92.10	89.00
F_6	95.60	91.33
F_7	96.70	93.33
F_8	98.43	96.67
Gaja local	94.10	90.67
INFM 95001	91.00	89.67
G.M	94.46	91.13
S.Em+	1.1461	1.3824
CD 5%	2.3907	2.8837
CV%	2.34	2.60

The results obtained in table 4.7 showed heterosis percentage over the mid parent. The heterosis percentage was maximum in vigour index II (15.206%) followed by seedling dry weight (12.84%) and 1000 seed weight (11.22%). The minimum heterosis percentage was observed for the characters, viz, germination percentage (0.554%) followed by viability (2.83%) and shoot length (3.819%).

The heterosis percentage over better parent (heterobeltosis) was represented in table 4.7. The heterobeltosis was maximum in vigour index II (11.45%) followed by seedling dry weight (5.655%) and vigour index I (4.68%). The minimum heterobeltosis percentage was observed for the characters viz, viability (1.13%) followed by seedling length (3.325%) and root length (3.449%). The negative heterobeltosis percentage was observed for seed quality characters viz, 1000 seed weight (-0.36%) and seedling fresh weight (-0.6.73%).

4.4 Correlation coefficient.

Correlation coefficient among the field and seed quality characters was worked out in all the possible combination. The result shows that some characters were highly significant as discussed below.

4.4.1 Field parameters

4.4.1.1. Days to maturity

Days to maturity showed positive and significant correlation with finger width (0.4938), finger length (0.4180), days to 50% flowering (0.7244) and plant height. The non significant and positive correlation was recorded in grains yield per ear head, number of grain per finger, ear bearing tillers, flag leaf length, number of leaves and plant height at maturity. However a non significant and negative correlation was recorded with number finger per ear and flag leaf width (Table 4.5).

4.4.1.2. Grain yield per Ear head

Grain yield per ear head showed a positive and significant correlation with finger width (0.4392), number of grains per finger (0.8585). The significant and negative correlation was seen in number of tillers (-0.4392). However positive but non significant correlation was seen in finger length, number of finger per ear and flag leaf length. The negative and non significant correlation was recorded with ear bearing tillers, number of tillers, flag leaf width, number of leaves and plant height.

4.4.1.3. Finger width

Finger width showed a positive and significant correlation with flag leaf length (0.5132). the positive and non significant correlation was observed in finger length, number of grains per finger, number of tillers, days to flowering, flag leaf width and plant height. However the negative and non significant correlation is recorded with ear bearing tillers and number of leaves (Table 4.5)

4.4.1.4. Finger length

Finger length exhibited positive and significant correlation with ear bearing tillers (0.5102), number of tillers (0.4714), plant height at 60 days (0.6443) and plant height at 30 days. The positive but non significant was recorded in number of grains per finger, days to 50 % flowering, flag leaf length and plant height at maturity, while negative and non significant correlation was observed with number of finger per ear, flag leaf width and number of leaves.

4.4.1.5. Number of grains per finger

Number of grains per finger showed negative and significant correlation with ear bearing tillers (-0.4829), number of tillers (-0.4431) and number of leaves (-0.7154). But positive and non significant correlation was recorded with days to 50 % maturity and flag leaf length (0.0559). The negative and non significant correlation was recorded in number of fingers per ear, flag leaf width and plant height.

4.4.1.6. Number of fingers per ear

Number of finger per ear exhibited positive and significant correlation with number of leaves per plant (0.5205). The positive but non significant correlation was observed in ear bearing tillers, number of tillers, flag leaf width and flag leaf length. However negative and non significant correlation was recorded days to 50 % flowering and plant height (Table 4.5).

4.4.1.7 Ear bearing tillers

Ear bearing tillers showed positive and significant correlation with number of tillers (0.6226) plant height at 60 days (0.5382), and plant height at 30 days (0.4865). But the positive and non significant correlation was recorded for days to maturity, flag leaf length, number of leaves per plant and plant height at maturity. The negative and non significant correlation is observed in flag leaf width.

4.4.1.8. Number of tillers

The number of tillers per plant showed positive and significant correlation with plant height at 60 days (0.6183). However the positive and non significant correlation was recorded in days to 50 % maturity flag leaf length, number of leaves, plant height at maturity and plant height at 30 days.

4.4.1.9. Days to 50 % flowering

Days to 50% flowering showed positive and significant correlation with plant height at 60 days (0.4469) and plant height at 30 days (0.4724). But the positive and non significant correlation was observed for the flag leaf length, number of leaves and plant height at maturity. The negative and non significant correlation was seen with flag leaf width.

4.4.1.10. Flag leaf width

Flag leaf width exhibited positive and significant correlation with plant height at maturity (0.5492). The positive and non significant correlation was observed with flag leaf length and number of leaves. But the negative and non significant correlation was recorded with plant height at 60 days and plant height at 30 days.

4.4.1.11. Flag leaf length

Flag leaf length showed positive and significant correlation with plant height at maturity (0.5949) and plant height at 60 days (0.5043). But the positive and non significant was observed in number of leaves and plant height at 30 days.

4.4.1.12. Number of leaves per plant

Number of leaves per plant showed positive and non significant correlation with plant height at maturity, plant height at 60 days and plant height at 30 days.

4.4.2. Seed quality parameters

4.4.2.1. Seed viability

The seed viability showed negative and highly significant simple correlation with test weight (-0.5078) in (Table 4.6).

Table 4. 5. Simple correlation between various quantitative characters of different generations of finger millet

Characters	Days to maturity	Grain yield (gm)	Finger width (cm)	Finger Length (cm)	No of Grain/ finger	No of finger/ Ear	Ear bearing tillers	No of tillers	Days to 50% flowering	Flag leaf width (cm)	Flag Leaf Length (cm)	No of leaves	Plant Height At maturity	Plant Height 60 days	Plant Height 30 days
Days to maturity	1.000	0.0541	0.4938*	0.4180*	0.0255	-0.0803	0.2700	0.3543	0.7244**	-0.1150	0.3204	0.2487	0.2001	0.4852*	0.4795*
Grain yield (gm)		1.0000	0.4392*	0,0839	0.8585**	0.1080	-0.3734	-0.4463*	0.1588	-0.1913	0.0519	-0.5051	-0.3110	-0.0260	-0.0873
Finger width (cm)			1.0000	0.3195	0.3895	-0.0930	-0.1171	0.0471	0.3217	0.0733	0.5132*	-0.0493	0.1317	0.3830	0.2255
Finger length (cm)				1.0000	0.0169	-0.2067	0.5102*	0.4714*	0.3332	-0.1078	0.2182	-0.1023	0.2552	0.6443**	0.5305**
No of grain/finger					1.0000	-0.2334	-0.4829*	-0.4431*	0.2127	-0.1389	0.0559	-0.7154**	-0.2068	-0.0721	-0.0767
No of finger/Ear						1.0000	0.1512	0.0638	-0.0613	0.1572	0.0897	0.5205**	-0.0078	-0.0325	-0.3044
Ear bearing tillers							1.0000	0.6226**	0.1394	-0.1410	0.1001	0.4111	0.3316	0.5382**	0.4865*
No of tillers								1.0000	0.2270	-0.0446	0.3209	0.4139	0.3933	0.6183**	0.3052
Days to 50%flowering									1.0000	-0.1498	0.1847	0.0004	0.0966	0.4469*	0.4724*
Flag leaf width (cm)										1.0000	0.2854	0.2285	0.5492**	-0.1068	-0.2044
Flag leaf length (cm)											1.0000	0.0641	0.5949**	0.5043*	0.1235
No of leaves												1.0000	0.1375	0.0045	0.0064
Plant height (maturity)													1.0000	0.3097	0.1568
Plant height (60 days)														1.0000	0.7084**
Plant height(30 days)															1.0000

*** 5% level of significance**
**** 1% of significance**

4.4.2.2. Germination

The phenotypic correlation of germination was observed positive and highly significant with viability (0.8820) and negatively significant with test weight (-0.5351).

4.4.2.3. Root length

The phenotypic correlation of root length was recorded positive and significant with test weight (0.4690). However the positive and non significant correlation was recorded with germination and viability (Table 4.6).

4.4.2.4. Shoot length

The shoot length showed positive and significant correlation with root length (0.6881), while the positive and non significant correlation was observed with germination percent and test weight. The negative and non significant correlation was recorded with viability.

4.4.2.5 Seedling length

The seedling length showed positive and significant correlation with shoot length (0.7487), root length (0.8888) and test weight (0.3633). The positive and non significant correlation was recorded with germination. But the negative and non significant correlation was observed in viability.

4.4.2.6. Seedling fresh weight

The simple correlation was computed between seedling fresh weight and other seed quality parameters showed the association of seedling fresh weight was positive and significant with root length (0.4506) and seedling length (0.4556). The positive and non significant correlation was recorded with seedling dry weight (0.0699) shoot length (0.2329) germination (0.2888) and viability (0.1688). However the negative and non significant correlation was recorded with test weight (0.0069) in (Table 4.6).

4.4.2.7. Seedling dry weight

The simple correlation between seedling dry weight and other seed quality parameter showed the positive and non significant with seedling length (0.3239), shoot length (0.3131), root length (0.3132), germination (0.1156), viability (0.1257) and test weight (0.0951).

4.4.2.8. Seedling moisture content

The seedling moisture content showed positive and significant correlation with seedling fresh weight (0.3667). The negative and significant correlation was recorded seedling dry weight (0.7027). However the positive and non significant correlation was recorded seedling length (0.0561), root length (0.0443), germination (0.0965) and viability (0.0032). The negative and non significant was recorded with shoot length and test weight.

4.4.2.9. Vigour index I

The vigour index showed positive and non significant correlation with seedling length (0.6189), shoot length (0.5154), root length (0.5526) germination (0.6129) and viability (0.5147). But positive and non significant was recorded with seedling moisture, seedling dry weight, seedling fresh weight and test weight (Table 4.6).

4.4.2.10. Vigour index II

The vigour index showed positive and non significant correlation was recorded with seedling dry weight (0.8820). The negative and significant correlation was observed in seedling moisture content (-0.6710). However the positive and non significant correlation was seen in vigour index I, seedling fresh weight, seedling length, shoot length, root length, germination, viability and test weight.

Table 4. 6. Simple correlation between various laboratory characters of different generations:

	Vigour index II	Vigour index I	Seedling Moisture content	Seedling Fresh weight	Seedling Dry Weight	Seedling Length (cm)	Shoot Length (cm)	Root Length (cm)	Germination %	Viability %	1000 seed weight
Vigour index II	1.0000	0.3003	-0.6710**	0.2665	0.8820**	0.2757	0.3339	0.3044	0.1870	0.1672	0.0123
Vigour index I		1.0000	0.1067	0.5113	0.2859	0.6189**	0.5154**	0.5526**	0.6129**	0.5147**	0.0162
Seedling moisture			1.0000	0.3667*	-0.7027**	0.0561	-0.1638	0.0443	0.0965	0.0032	-0.0911
Seedling fresh wt				1.0000	0.0699	0.4556**	0.2329	0.4506**	0.2888	0.1687	-0.0069
Seedling dry wt					1.0000	0.3239	0.3131	0.3121	0.1156	0.1257	0.0951
Seedling length						1.0000	0.7487**	0.8888**	1.0885	-0.1062	0.3633*
Shoot length							1.0000	0.6881**	1.0034	-0.0162	0.3028
Root length								1.0000	1.1410	-0.1637	0.4696**
Germination %									1.0000	0.8820**	-0.5351**
Viability %										1.0000	-0.5078**
1000 seed weight											1.0000

**** 5 % Level of significance**

*** 1% Level of significance**

Table: 4.7 Performance of F_1 generation over mid parent and better parent in different seed quality parameters.

Characters	Female parent	Male parent	Mid parent	F_1 Generation	% Heterosis	% Heterobeltosis
1000 seed weight	4.123	3.264	3.693	4.108	11.22	-0.36
Viability %	91.00	94.10	92.55	95.17	2.83	1.13
Germination %	89.67	90.67	90.17	90.67	0.554	0.00
Root length	6.493	6.063	6.278	6.717	6.992	3.449
Shoot length	6.137	6.063	6.100	6.333	3.819	3.193
Seedling length	12.63	12.28	12.445	13.05	4.869	3.325
Seedling dry weight	0.0116	0.0103	0.0109	0.01233	12.84	5.655
Seedling fresh weight	0.1723	0.1353	0.1538	0.1607	4.4863	-6.73
Vigour index I	1131.00	1114.00	1122.5	1184.00	5.478	4.68
Vigour index II	1.004	0.9387	0.9713	1.119	15.206	11.45

Table 4.8 Estimates of range, mean and variability of different field characters.

Characters	range	mean	PCV%
Plant height at 30 days	41.77-53.70	46.75	9.37
Plant height at 60 days	81.03-109.2	98.93	9.44
Plant height at maturity	114.6-123.4	119.0	2.38
Number of leaves	9.66-14.00	10.77	13.05
Days to 50% flowering	103.0-125.6	108.2	6.99
Number of tillers per plant	2.00-4.00	2.791	25.48
Number of ear bearing tillers per plant	1.00-3.00	1.75	40.41
Number grains per finger	5.66-7.66	6.708	37.96
Finger length	5.10-9.16	7.10	18.31
Finger width	0.86-1.73	1.28	22.06
Days to maturity	143.7-178.0	150.03	76.31
Grain yield per ear head	1.18-7.47	4.95	45.77

Table 4.9 Estimates of range, mean and variability of different seed quality parameters.

Characters	range	mean	PCV%
1000 seed weight	2.684-4.123	3.538	13.00
Viability %	91.00-98.43	94.46	2.34
Seedling fresh weight	0.112-0.172	0.145	31.22
Seedling dry weight	0.0080-0.0163	0.0113	20.04
Seedling moisture	84.33-94.35	91.83	3.01
Vigour index I	1083.56-1194.36	1141.11	3.14
Vigour index II	0.707-1.447	1.032	20.53

Table 4.10 Mean sum of square of field parameters:

Characters	Mean Square		
	Replication	treatment	Error
Degree of freedom	2	7	14
Plant height (cm) 30 Days	1.5837	57.65*	5.9166
Plant height (cm) 60 Days	6.97	262.33*	30.60
Plant height (cm) at maturity	14.858	24.425*	27.335
Number of leaves	2.7917	5.8512*	1.3155
Flag leaf length (cm)	3.7363	28.03	15.135
Flag leaf width (cm)	0.0168	0.180	0.0208
Days to 50% flowering	0.04116	16.613*	3.6131
Number of tillers/plant	0.5416	2.5714*	0.589
Number of ear bearing tillers	0.50	1.50*	0.50
Number of finger/ear	0.333	6.9583	17.66
Number of grain / finger	159.25	14652*	914.08
Finger length (cm)	0.461	5.082*	0.619
Finger width (cm)	0.0929	2.3119*	0.0958
Grain yield (g)	1.833	15.412*	0.9618
Days to maturity	0.7916	396.52*	5.696

*** 5% level of significance**
**** 1% of significance**

Table 4.11 Mean sum of square of seed quality parameters.

Character	Mean	
	Treatment	Error
Degree of freedom	9	20
Test weight (g)	0.635**	2.596
Viability percentage	14.736**	1.9703
Seedling fresh weight (g)	0.00145**	0.000729
Seedling dry weight (g)	0.0001566*	0.0000370
Germination percentage	16.904**	2.8867
Shoot length (cm)	0.034018	0.5574
Root length (cm)	0.14399	0.090220
Seedling length (cm)	0.18533	0.18680
Vigour index I	3839.7*	2471.2
Vigour index II	0.13424**	0.02916
Seedling moisture percentage	23.030**	3.2109

***   5% level of significance**
**** 1% of significance**

DISCUSSION

Millets are very important crops for the difficult Himalayan conditions as they have high nutritional value and are one of the cheapest sources of dietary energy, in the form of proteins and carbohydrates. Such crops are particularly in the mountains where most of the population depends on vegetable proteins and carbohydrates as dietary staples. Traditionally in the Himalayas many of these traditional crops supplement the wheat and rice meals. The production of millets in uttarakhand could be given focus to achieve self sufficiency. Millets production zones and cropping pattern could be augmented and steamlined for attaining sustainable and optimum production. Millets in uttarakhand are grown under organic forming and some of the organically produced grains are being used for the of nutritionally rich baby food.

Economic yield of any crop depends on the quality of seed, which can be evaluated prior to sowing by seed test (ISTA, 1996). Thus, to improve the existing genotype(s) to a desired level and to develop superior genotypes a better understanding of the viability, vigour, and its component is necessary. It has been widely recognized that seed size, weight and other attributes play important role in determining seed quality, vigour, seedling establishment, crop performance and ultimately seed yield.

The major objective of testing seed germination and vigour is to predict some aspect of potential plant performance particularly seedling growth rate, seedling emergence, fresh and dry weights of plants and finally crop yield. Important factors which influence the quality of seed are the genotypes and physiological characteristics of the seeds.

Information regarding the extent of genetic variability in the experimental material for seed quality and other quality contributing characters, their genetic makeup, the correlation between different characters, their effect on seed yield and prediction of seedling vigour on the basis of performance of component characters should assist a seed technologist in formulating the appropriate selection strategies and assurance of seed quality.

Quality of seeds may be affected with their position with in panicle. The pattern of seed growth and final weight vary among genotypes as well as among positions in the panicle (Hamilton *et al.*1982; Heinger *et al.* 1993).

Therefore, present investigation was planned for the study of seed quality parameter in different generation of finger millet, at the experimental farm and laboratories of Seed Science and Technology, G. B. Pant university of Agriculture and Technology, Hill Campus, Ranichauri, Distt. Tehri Garhwal, Uttarakhand

5.1 Variability Studies

It is an established fact that greater variability would lead to better scope for selection and predicting accurately the yield of a crop. Moreover, the phenotypic variability arises due to the genotypic and environmental influences. Therefore, for framing an appropriate selection programme, information about the extent of variability is very essential.

The significant mean square due to mean female x male interaction for all the traits differed significantly for only a few traits, which suggest that female x male interaction resulted in increased genetic differentiation in the crosses for all the traits, which is supported by significant mean square due to crosses (Sumithi *et al*.).

The genetic variability for productivity traits in finger millet such as plant height, number of tillers per plant, productive tillers per plant, days to 50% flowering, days to maturity, number of finger per ear, length of finger, flag leaf length, grain yield per plant. The observed variability on different characters was similar observation was suggested by Satish *et al*. (2004)

Finger millet is considered as short day plant and usually an erect annual, 60 to 120 cm tall, with few tillers and adventitious root system. In present investigation considerable amount of variability was recorded for both qualitative and quantitative characters

5.1.1 Qualitative characters

The plants of different accessions were observed to have different shape of inflorescence which was either loose or compact in various generation plants. Variability was also observed with respect to colour of seed i.e. white, light brown and brown which was also reported by Balternsporger *et al*. (1995).

The finger millet shows two distinct type of seed coat colour have been recognized, namely brown and white. Amazingly high amount of protein is coupled with the occurrence of white seed coat colour in finger millet. To understand the genetic basis of inheritance of seed coat colour a study was conducted by (Gurunathan, *et al.*) The parent CO 9 (white type) and TNAU 946 (brown type) were selected for crossing during kharif. The F_1 seed were brown seed coat colour this shows the brown seed coat colour is dominant over white seed coat colour. F_2 population consists of 164 plants. Among them, 159 plants produced brown seed coat colour and 5 plants were produced white seed coat colour.

5.1.2 Field parameters

The extent of variability in different generations for various morphological characters were recorded and significant variations were observed for days to maturity from 143.7 days (F_7 generation) to 178.0 days (INFM 95001 line), plant height at 30 days from 41.77 cm (F_6 generation) to 53.70 cm (Gaja local line), seed yield per plant from 1.182 g (INFM 95001 line) to 7.473 (F_2 generation), finger length from 5.10 cm (F_7 generation) to 9.16 cm (Gaja local line) and finger width from 0.86 cm (F_6 generation) to 1.73 cm (F_2 generation).

The large extent of variability in all these characters might have resulted due to diverse origin of accession coupled with environmental interaction. Similar result were also reported by Mnyenyembe and Gupta (1998) For plant height day to 50 per cent flowering, grain yield in finger millet, Gowda *et al*. (2003) for flag leaf length, flag leaf width in proso millet

5.1.3 Seed quality parameter

The concept of seed quality is a complex one having several aspects. In India and other developing countries good quality seeds are the “Seeds of Green Revolution” therefore, it is imperative to understand the mechanism of seed quality and its components. The physiological quality of seed relates to its vigour, viability and other seed quality parameters.

Germination per cent showed range of variability from 88.33 % (F_4 generation) to 96.67 % (F_8 generation), root length from 6.063 cm (Gaja local) to 6.71 cm (F_1 generation), shoot length from 6.013 cm (F_7 generation) to 6.33 cm (F_1generation), test weight from 2.684 g (F_8 generation) to 4.123 g (INFM 95001 line), seedling vigour index I from 1083.56 (F_4 generation) to 1194.36 (F_8 generation) and seedling moisture content from 84.33% (F_3 generation) to 94.35% (F_7 generation). These findings were in accordance with the results of Krisnappa *et al.* (2002).

In laboratory conditions germination percent, seedling fresh weight, test weight, seedling dry weight, seedling moisture content, seedling vigour index I, vigour index II and viability test was showed a significant variation among the generations. Each generation showed unique characters for these parameters. This is in accordance with the finding of Rahangdale *et al*. (1995). **5. 4 Character Association**

5.4.1 Correlation in Field performance

Yield is a complex polygenic character the genotypic improvement of which depends upon the knowledge and extent of its association with various component characters. An understanding of the association among the different component characters and relative contribution to yield is essential to bring a rational improvement in the deserved traits.

Days to maturity showed positive and significant correlation with finger width, finger length, and days to 50% flowering and plant height. This was supported by Abhram *et al.* (1989).

Seed yield per plant showed significant and positive correlation with finger width, number of grin per finger, This indicates that high yield in finger millet could be achieved with selection on the basis of expression of these characters, which was supported by Sen and Hamid (1986)

Finger length showed positive and significant correlation with ear bearing tillers, number of tillers, plant height at 60 days and plant height at 30 days. Similar correlations for these traits have been reported earlier by Kishan Reddy (1994) and Cauvery (1993).

5.4.2 Correlation in laboratory performance

Vigour index I reported significant and positive correlation with viability, germination per cent, root length, shoot length and seedling length. Which are some of its determining characters. Similar observation were reported by Roy et al. (1997) in pigeon pea and Singh and Chaudhry (1994) in sorghum.

Seedling fresh weight showed positive and significant correlation with seedling length, root length. This was supported by maloo et al. (1990) and Mehta et al. (2003).

Standard germination per cent revealed significant and positive correlation with viability percent and test weight. The results were supported by Hoy and Gambe (1987), Bajpai et *al*. (1992) and verma *et al*. (2001).

SUMMARY AND CONLUSION

The present investigation entitled Studies on seed quality parameters in different generations of finger millet (*Eleusine coracana* (L) Gaertn)" was conducted in experimental farm and laboratory of the Department of Seed Science and Technology, Hill Campus, Ranichauri during *Kharif* 2006. The present study was initiated with objective to study the performance of finger millet generations for seed quality parameters and characterization of finger millet generation by means of morphological and physiological parameters in seven generations of finger millet.

Correlation for field and seed viability parameter was also estimated with a view to understand the physiological and morphological behaviour of the expression of character. Their association and contributions to main seed quality and economic yield. The experimental material comprised of two parent (Gaja local and INFM 95001 male sterile line) and seven generation seeds were obtained from Genetics and Plant breeding Section, Hill Campus, Ranichauri. The crop was raised in Randomized Complete Block Design with three replications. Observations were recorded for various morphological, qualitative, quantitative characters and seed quality parameters. The data obtained during the course of study were analyzed statistically for various traits.

Morphological parameters were studied under two broad heads quantitative and qualitative characters. In qualitative characters, plants were studied for shape of the ear head and seed colour. Sufficient amount of variability was found in these characters. Quantitative character studied also showed the variability. The extent of variability in different generation was recorded and significant variations were found:

- The maximum and minimum ranged for plant height at 30 days was recorded 53.70 cm (Gaja local) to 41.77 cm (F_6 generation).
- The highest and lowest finger length was observed 9.167cm (Gaja local) to 5.1cm (F_7 generation).
- The extent of variation for number of grain per finger was 34.67 (INFM 95001line) to 300.7(F_2 generation).
- The minimum and maximum value for days to 50% flowering ranged from 103.0 (F_7 generation) to 125.6 (INFM 95001).
- The lowest and highest seed yield per ear head was observed 1.182 g in INFM 95001 line and 7.473 g in F_2 generation.
- The extent of variation for number of leaves per plant was 9.66 (F_5 generation) to 14.0(INFM 95001line).

Assessment of quality was the main concern of the present investigation. Seed quality is assessed for various morphological and physiological parameters with respect to various seed quality parameters viz. germination per cent, seedling fresh weight, seedling dry weight, viability test, seedling vigour index I, seedling vigour index II and seedling moisture content. The comparative study was also made among the field and laboratory evaluation for seed quality parameter quality parameters.

The data thus obtained were statistically analysed and it was concluded that:

- The minimum and maximum range for 1000 seed weight ranged from 2.684g (F_8 generation) to 4.123g (INFM 95001 line).
- The viability percentage was maximum in F_8 generation (98.47%).
- The germination percentage was maximum in F_8 generation (96.67%) and minimum in F_4 generation.
- The extent of variation for seedling moisture content was 84.33% (F_3 generation) to 94.35% (F_7 generation).
- The lowest and highest seedling vigour index II was observed 0.707 (F_4 generation) to 1.47 (F_3 generation).

The extent of heterosis in ten seed quality character was investigated for some character, 1000 seed weight, viability, germination percent, root length, shoot length, seedling dry weight, seedling fresh weight, vigour index I and vigour index II. For each character percent of heterosis over mid and better parent was calculated. The percent heterosis was observed maximum in seedling vigour index II, seedling dry weight and 1000 seed weight.

The character associations were also made for morphological and seed quality parameter. The positive and significant correlation was showed by days to maturity with plant height (30 and 60days), days to 50% flowering, finger length and finger width. The finger length showed positive and significant correlations with number of tillers per plant, ear bearing tillers per plant, plant height at 30 days and plant height at 60 days were found. Similarly simple correlation of laboratory characters was studied. Seedling vigour index I showed positive and significant correlation with seedling length, shoot length, root length, germination percentage and viability.

Conclusion

Out of 8 generation and two parent of finger millet, an over view of the result from the present investigations demonstrated the presence of a wide spectrum of morphological variation in generations. It can be concluded that among the generations studied F_1 generation and F_2 generation showed a desirable traits for seed quality and seed yield per plant. These generations are can be adopted for further breeding improvement purpose.

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VITAE

The author, son of Mr. Gundappa Patil was born on 1st June 1983 at Basavakalyan, Bidar, Karnataka. He passed his High School and Intermediate examinations in 1999 and 2001 respectively from Nagareshwar high school and Govt Jr College Humnabad. In 2005 he did his graduation in B.Sc. (Ag) from UAS Dharwad. He joined G.B. Pant University of Agriculture & Technology, Pantnagar in 2005 through ICAR entrance examination for the degree of M.Sc. (Ag.), Seed Science and Technology. During the period of his Post Graduate studies he was awarded with ICAR Junior research Fellowship.

Address

Mr. Kalyanrao Patil
S/o Gundappa Patil
Post. Hipparga(bag)
Tq . Basavakalyan
Dist. Bidar, KARNATAKA
Tel. 08483-270005
Email : patil_kalyan@rediffmail.com

ABSTRACT

Name: Kalyanrao Id. No. 32878

Year of admission: august, 2005 Department: Seed Science and Technology

Degree: Master of Science in Agriculture Major: Seed Science & Technology

Thesis title: STUDIES ON SEED QUALITY PARAMETERS IN DIFFERENT GENERATIONS OF FINGER MILLET (*Eleusine coracana* (L) Gaertn.)

Advisor: Dr. Rajendra Prasad, Professor & Head, Department of Seed Science and Technology, G.B. Pant University of Agriculture & Technology, Hill Campus, Ranichauri.

The present investigation was conducted during *Kharif* 2006, at Hill Campus, Ranichauri with seven generation and two parents. The experiment was laid out in randomized block design with three replication. Characters were studied for variability viz. shape of ear head, seed colour, plant height (at 30 days, 60 days and maturity), flag leaf length, flag leaf width, number of leaves per plant, finger length, finger width, number of grain per finger, number of tillers per plant, number of ear bearing tillers per plant, days to 50% flowering, days to maturity and seed yield per plant. seed quality parameters viz. 1000 seed weight, root length, shoot length, fresh weight of seedling, dry weight of seedling, seedling moisture content, viability percentage, germination per cent, vigour index I and vigour index II. Character association was also computed for field and seed quality parameters.

Significant differences in quantitative characters were observed. The plant height at 30 days ranged from 41.77 cm (F_6 generation) to 53.70 cm (Gaja local), plant height at 60 days ranged from 81.03cm (F_7 generation) to 109.2cm (Gaja local), plant height at maturity 114.6cm (F_7 generation) to 123.4cm (INFM 95001), days to 50% flowering 103.0 days (F_7 generation) to 125.6 days (INFM 95001), finger length 5.10cm (F_7 generation) to 9.16cm (Gaja local), finger width ranged from 0.866cm (F_6 generation) to 1.733 (F_1 generation), number of leaves 9.66 (F_5 generation) to 14.00 (INFM 95001), number of tillers per plant ranged from 1.0 (F_7 generation) to 4.00 (INFM 95001), number of ear bearing tillers per plant 1.00 (F_7 generation) to 3.00 (INFM 95001), number of grain per finger ranged from 34.67 (INFM 95001) to 300.70 (F_1 generation), days to maturity 143.7 (F_7 generation) to 178.0 (INFM 95001), seed yield per ear head 1.182 g (INFM 95001) to 7.473 g (F_1 generation). 1000 seed weight ranged from 2.684 (F_8 generation) to 4.123(INFM 95001), germination % varies from 88.33 % (F_4 generation) to 96.67 % (F_8 generation), seedling fresh weight 0.112 (F_4 generation) to 0.172 (INFM 95001), seedling dry weight 0.0080 (F_4 generation) to 0.0163 (F_3 generation), viability percent ranged from 91.00% (INFM 95001) to 98.43 (F_8 generation), seedling moisture content varies from 84.33% (F_3 generation) to 94.35% (F_7 generation), vigour index I ranged from 1084.0 (F_4 generation) to 1194.0 (F_8 generation), vigour index II 0.707 (F_4 generation) to 1.147 (F_3 generation).

Advisor Author