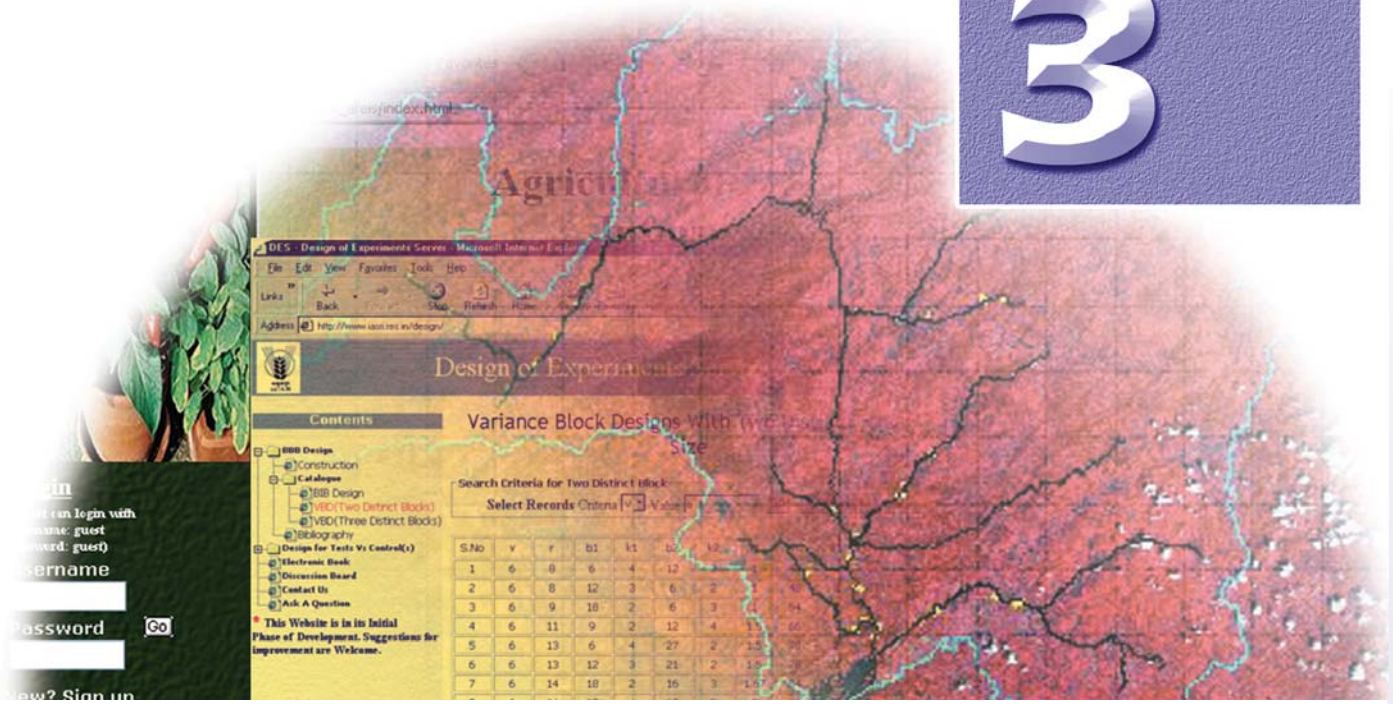


Research Achievements

The research targets set by the Institute were implemented by six Divisions of the Institute viz. Sample Survey, Design of Experiments, Biometrics, Forecasting Techniques, Econometrics and Computer Applications. The basic, applied adaptive and strategic research in Agricultural Statistics and Computer Application is carried out under six broad programmes that cut across the boundaries of the Divisions and encourage interdisciplinary research. The six programmes are as under:

1. Development and analysis of experimental designs for agricultural systems research
2. Forecasting and remote sensing techniques and statistical applications of GIS in agricultural systems
3. Development of techniques for planning and analysis of survey data including economic problems of current interest
4. Modelling and simulation techniques in biological systems
5. Development of information technology in agricultural research
6. Teaching and training in Agricultural Statistics and Computer Application

PROGRAMME 1: DEVELOPMENT AND ANALYSIS OF EXPERIMENTAL DESIGNS FOR AGRICULTURAL SYSTEMS RESEARCH

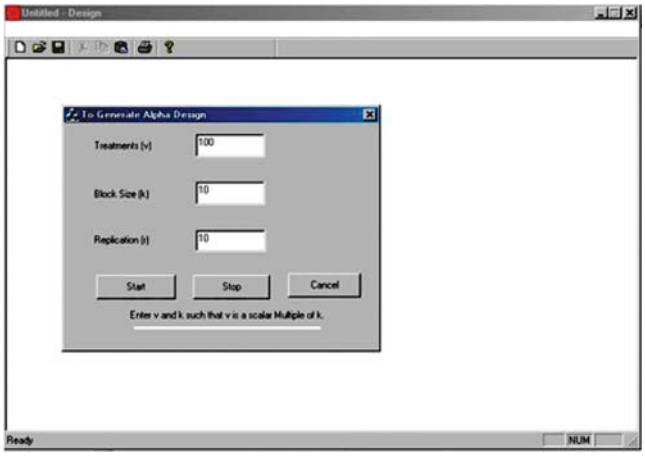
Efficient Design of Experiments for Quality Agricultural Research (National Fellow Scheme)

In field trials, large number of crop varieties cannot always be laid out in a single location or a single season. Therefore, it is desired that variation due to location or time periods may also be controlled along with controlling within location or time period variation. This can be handled by using resolvable block designs. α-designs are essentially resolvable block designs. In a resolvable block design, the blocks can be grouped such that in each group, every treatment appears exactly once. Resolvable block designs allow performing an experiment with one replication at a time.

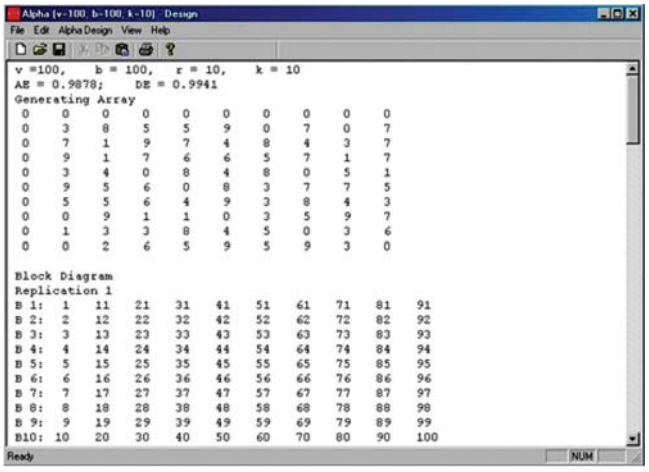
Here, locations or time periods may be taken as replications and the variation within a location or a time period can be taken care of by blocking. In an agricultural field experiment, the land may be divided into a number of large areas corresponding to the replications and then each area is subdivided into blocks. These designs are also quite useful for varietal trials conducted in the National Agricultural Research System (NARS) and will help in improving the precision of treatment comparisons. A critical look at the experimentation in the NARS reveals that α-designs have not found much favour from the experimenters. It may possibly be due to the fact that the experimenters find it difficult to lay their hands on α-designs. The construction of these designs is not easy. An experimenter has to get associated with a statistician to get a randomized layout of this design. For the benefit of the experimenters, a comprehensive catalogue of α-designs for $6 \le v\,(=sk) \le 150$, $2 \le r \le 5$, $3 \le k \le 10$ and $2 \le s \le 15$ has been prepared along with lower bounds to A and D efficiencies and generating arrays. The layout of these designs along with block contents has also been prepared. The designs obtained have been compared with corresponding square lattice, rectangular lattice, resolvable two-associate class partially balanced incomplete block {PBIB(2)} designs and the α-designs obtainable from basic arrays given by Patterson, Williams and Hunter (1978, *J. Agric. Sci.*, **90**, 395-499). Eleven designs are more efficient than the corresponding resolvable PBIB(2) designs (S11, S38, S69, S114, LS8, LS30, LS54, LS76, LS89, LS126 and LS140). It is interesting to note here that for the PBIB(2) designs based on Latin Square association scheme, the concurrences of the treatments were 0 or 2 and for singular group divisible designs the concurrences are either 1 or 5. Further all the designs LS8, LS30, LS54, LS76, LS89, LS126 and LS140 were obtained by taking two copies of a design with 2-replications. 10 designs were found to be more efficient than the designs obtainable from basic arrays. 48 designs (29 with $k = 4$ and 19 with $k = 3$) are more efficient than the designs obtainable by dualization of basic arrays. 25 designs have been obtained for which no corresponding resolvable solution of PBIB(2) designs is available in the literature. The list of corresponding resolvable PBIB(2) designs is S28, S86, SR18, SR41, SR52, SR58, SR66, SR75, SR80, R42, R70, R97, R109, R139, T14, T16, T20, T44, T48, T49, T72, T73, T86, T87 and M16. Here X# denotes the design of type X at serial number # in Clatworthy, W. H. (1973, *Table of Two-associate Partially Balanced Designs*. NBS Applied Maths Series No. **63**, Washington D.C.).

In some experimental situations, the user may be interested in getting designs outside the above parametric range. To circumvent such situations, a β-version of user friendly module for generation of α-designs has been developed. This module generates α-array along with lower bounds to A and D efficiency. α-array and the design along with block contents is generated once the user enters the number of treatments (v), number of replications (r) and the block size (k), provided v is a multiple of k.

A nested block design is defined as two systems of



The Screen for entering the parameters for generation of α-designs



Generated α-array and α-design for the parameters

blocks such that the second system of blocks is nested within the first system of blocks. These designs are quite useful in many experimental situations. For example, consider a field experiment conducted using a block design and harvesting is done block wise. Harvested samples are to be analyzed for their contents either by different technicians at same time or by a technician over different periods of time. The variation due to technicians or time periods may be controlled by another blocking system. Technicians or time periods form a system of blocks that are nested within blocks. Such experimental situations are also common in post harvest value addition of horticultural and vegetable crops. Nested block designs are also quite useful in agricultural field experiments where the plots with similar fertility occur in patches rather than in a uniform direction. Preece, D.A. (1967, *Biometrika*, **54**, 479-486) was the first to introduce nested block designs and termed them as nested balanced incomplete block (NBIB) designs. In a NBIB design block classification ignoring sub-blocks is a balanced incomplete block (BIB) design and sub-block classification ignoring blocks is also a BIB design. A complete catalogue of NBIB designs with number of replications $r \leq 30$ has also been prepared. The catalogue contains a total of 299 designs. Out of 299 designs, 8 designs are non-existent. A new method of construction of NBIB designs has been obtained. Using this method and trial and error solutions, block layouts of 22 new NBIB designs have been obtained. The layout of 199 designs with block contents has been completed. The solution for the block layout for remaining 92 designs is unknown and the statisticians need to develop methods of construction of these NBIB designs. The designs catalogued have also been identified for 1-resolvable and 2-resolvable sets.

A NBIB design may not exist for all parametric combinations or even if it exists may require a large number of replications, which the experimenter may not be able to afford. To deal with such situations, nested partially balanced incomplete block (NPBIB) designs have been introduced in the literature. Some new methods of construction of NPBIB designs based on group divisible association scheme have been given using these methods of construction. 31 new NPBIB designs based on group divisible association scheme with $r \leq 15$ have been obtained.

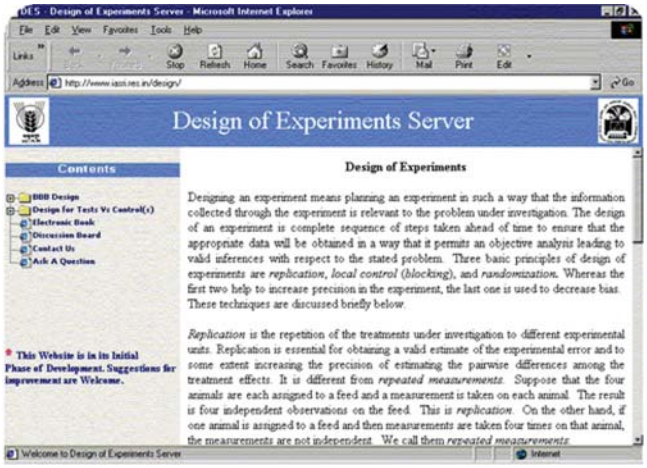
Nested block (NBIB and NPBIB) designs are useful for experimental situations where the experimenter is interested in making all possible pairwise treatment comparisons with as high a precision as possible. However, there do occur experimental situations where the experimenter is interested in comparing several new treatments (called test treatments) with existing practice (a control treatment) with high precision and the comparisons among the test treatments are not of much importance. To deal with such situations, nested balanced treatment incomplete block (NBTIB) designs have been introduced. Some new methods of construction of NBTIB designs making use of NBIB designs, initial block solutions, etc. have been developed. A new method of construction of nested block designs for making test treatments-control treatment comparisons has been developed which yields minimally connected designs with respect to sub-blocks. The design with respect to bigger blocks is a group divisible treatment design.

A new method of construction of efficient block designs for making test treatments-control treatment comparisons by making use of triangular association scheme has been developed. The number of replications of test treatments developed through this method is always 2.

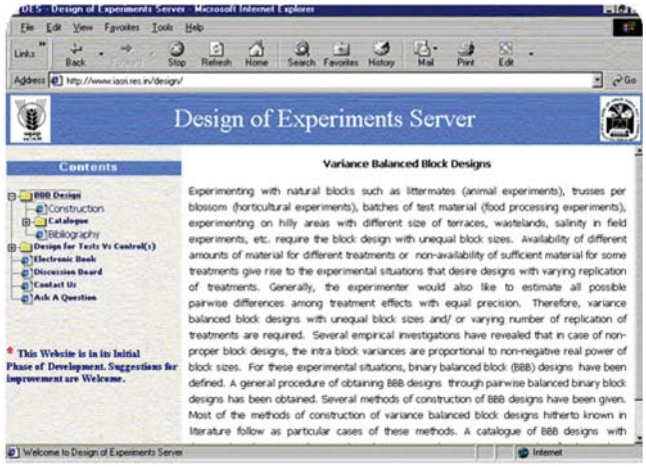
A new method of construction of semi-Latin Squares based on initial column solution has been developed. This method yields semi-regular group divisible designs after ignoring the row and column classifications. Preece and Freeman (1983*, J. Roy. Statist. Soc.*, **28**, 154-163) reported that for $k = 2, n = 6, 8, 10$ could not be obtained by rearrangement in semi-regular group divisible designs. These three semi-Latin Squares can be obtained from the proposed method of construction.

A catalogue of block designs with $n = v+b-1+i$, i=1, 2, 3 observations has been prepared, where v is the number of treatments; b is the number of blocks; k is the block size and n is the total number of experimental units. Block contents along with lower bounds to A and D efficiencies are also given. The lower bounds to A-efficiencies for making test treatments-control treatment comparisons are being obtained.

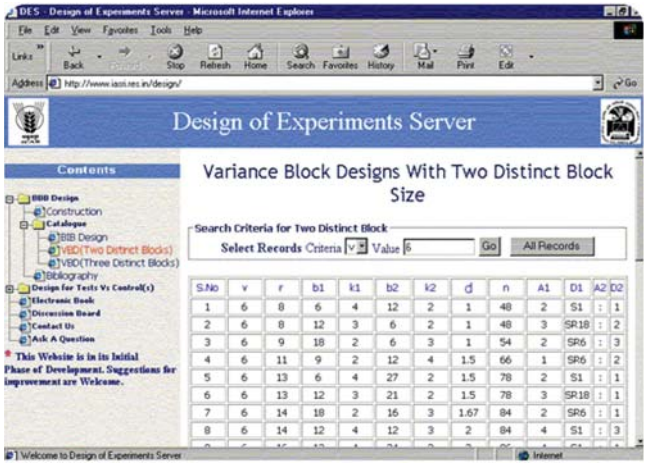
The design resources server has been initiated and launched on the website of the Institute. The main objective of this design resources server is to develop a WEB DESIGN in NARS. At present material on binary balanced block designs and designs for making test treatments-control treatment comparisons along with Electronic Book on Design and Analysis of Agricultural Experiments are available on this site. A discussion



First Screen of Design of Experiments Server



Binary Balanced Block Designs



Catalogue of Binary Balanced Block Designs with two Distinct Block Sizes

board has been created. Some screens are given in the Sequel.

Cropping Systems Research

In the project 'Planning, designing and analysis of experiments planned on-station under the Project Directorate for Cropping Systems Research', four types of research programmes are in operation viz. (i) development of new cropping systems, (ii) nutrient management in cropping systems, (iii) development of system based management practices and (iv) sustainable resource management. The data of about 320 experiments pertaining to 2004-05 crop year were received during 2005-06. Designs adopted for conduct of experiments during this year were RBD, split-plot, split-split plot, strip plot, factorial RBD, 3^2x2 partially confounded with one control in each of the three blocks per replication, BIB design and unreplicated design. For unreplicated experiments, data were analysed taking years as replications. For concluding experiments statistical analysis over years was taken up. At one of the CSR centre Jabalpur, an experiment on tillage and planting management in rice-wheat cropping system has been conducted during 2004-05. Four vertical treatments in rice viz. P_1 - zero till direct seeding (lime sowing) on dry fields, P_2 - direct seeding of sprouted seeds in puddled field by drum seeder, P_3 - manual transplanting and P_4 - transplanting by transplanter and 4 horizontal treatments in wheat viz., T_1 - conventional sowing, T_2 - zero till sowing, T_3 - strip till sowing and T_4 - bed planting were tested in strip plot design with three replications with regard to total productivity of entire cropping system in terms of wheat equivalent yield (WEY). P_2 produced maximum yield (87.86q/ha) followed by P_3 (85.49q/ha), P_4 (83.52q/ha) and P_1 (82.57q/ha). Among different methods of sowing of succeeding crop, T_3 produced the highest WEY (91.32q/ha) followed by T_2 (85.10q/ha), T_1 (82.33q/ha) and T_4 (80.19q/ha). The combination of P_3T_3 (manual transplanting of rice and strip till sowing of wheat) produced the highest WEY (93.06q/ha) while P_1T_4 (Direct seeding of rice and bed planting of wheat) (76.48q/ha) was the lowest yielder.

Preparation of instruction manual which is required to give guidelines for proper conduct of various types of experiments in the project is initiated.

Under the "On Farm Research" programme, mainly 3 types of experiments viz. (Expt. 1 : Response of Nutrients, Expt. 2 : Diversification and/or Intensification of Cropping System and Expt. 3 : Sustainable

Production System) have been undertaken at 32 On-Farm Centres. The data of 135 experiments (at 2223 farmers' field) conducted during 2004-05 at 32 on-farm centres have been processed for statistical analysis.

Under "Diversification/Intensification of cropping system experiment", in the rice based cropping sequence, trials have been conducted with different cropping systems at various centres. At Bankura (W.B.), Rice-Potato-Rice have fetched higher net returns (Rs. 54296/ha) in comparison to other crop sequences such as Rice-Mustard-Rice (Rs. 35537/ha) and Rice-Mustard-Bhindi (Rs. 36276/ha) etc. At Haridwar centre (Uttranchal), Rice-Wheat-Moong recorded higher net returns (Rs. 33476/ha) in comparison to Rice-Lentil-Urd (Rs. 30829/ha). In Southern Konka coastal region at Ratnagiri (Maharashtra), Rice-Wheat (Veg.) has reported a net return of Rs.17084/ha and Rice-Marigold has a net return of Rs.12558/ha. In low hills sub tropical zone at Dhaula Khua (H.P.) centre different vegetables such as Potato, Onion, Cabbage, Frenchbean have grown with Rice in *kharif* season. Rice-Wheat-Frenchbean, Rice-Onion, Rice-Cabbage and Rice-Potato have reported net return of the order of Rs.129303, Rs.108841, Rs.106998 and Rs. 93768/ha respectively.

Task Force on "Balanced use of fertilizer" constituted by Ministry of Agriculture, Govt. of India, requested for evaluation of fertilizer response ratios for different crops for various nutrients using on-farm trials, consequently data generated from the Expt. 1 (Response of nutrients) for 4 years 1999-2000 to 2002-03 have been used for the computation of various fertilizer response ratios (N over control, NP over control, NK over control, NPK over control, P over N, P over NK, K over N and K over NP) for various crops. Response ratios for cereals, pulses, oilseeds at state and country level have also been evaluated and are given in table below:

Crop group	Area 000 ha (2000-01)	Average control yield (kg/ha)	Average Response Ratio							
			N	NP	NK	NPK	P over		K over	
			Over control				N	NK	N	NP
Cereal	99757	1803	8.56	8.97	8.66	8.63	10.02	11.29	9.16	10.85
Oilseed	23250	897	8.53	5.19	6.91	5.27	4.48	5.48	6.02	7.88
Pulses	20026	586	8.11	7.53	8.97	7.12	7.22	5.95	12.09	5.32
Overall		1485	8.50	8.15	8.42	7.89	8.73	9.60	9.06	9.59

It is observed from the table that response ratio varies depending upon the crop group and nutrient combination applied. The highest response ratio is found to be 12.09 of K over N for pulses whereas minimum 4.48 is observed for P over N for oilseed crops. Also for overall, crops response ratio of NPK over control is less than the response ratio of N over control.

At all the centres under the AICRP on LTFE, 100%NPK+FYM treatment has been found most sustainable producing maximum yield or equivalent to that obtained with 150%NPK. With the well recognized role of organic manure in maximizing the yield responses so as to break off the yield barriers, mid course superimposition of FYM levels at 0, 2.5, 5 and 10 t per ha per year in one of the replications of 150%NPK treatment under nested two way set up has been planned at each of the locations for implementing mid course changes *w.e.f. kharif/rabi* 2005-06 as per the recommendation of the last workshop of the project held at PAU, Ludhiana in November, 2004.

The analysis of technological interventions treatments data like increasing the optimal NPK doses by 50%, incorporation/blending of Zinc/Lime/Hand Weeding(HW)/S and FYM with the optimal NPK doses of the crops were carried out on five yearly intervals as well as over the years (1972-2004) to see their effect on the crop productivity and soil fertility.The salient results obtained are as follows:

HW: Adoption of Hand Weeding over weedicides proved to be effective for maize at Ludhiana, for wheat at Pantnagar and for both the rice crops at Bhubneswar increasing their average yields over the years by 15, 7, 8.5 and 8% respectively. At rest of the locations significant decrease in crop yields were noticed. HW failed to improve soil fertility at any of the locations.

Zinc: Incorporation of zinc with optimal NPK showed its beneficial effect at Ludhiana and Pantnagar only after 10-12 years of experimentation. At Ludhiana its application increased maize yield by 4.2 q per ha during 1981-85 and by 12.4 q per ha during 1996-2000 over the average yield of 22 q per ha obtained without zinc. At Pantnagar the increase was about 6 q per ha for rice and ranged from 3 to 5.5 q per ha for wheat during different five yearly intervals. Application of zinc increased its availability in soils in all the groups of years as well as over the years vis-à-vis optimal NPK.

Lime: Soil application of lime under 100% NPK treatment taken up in Alfisol (Acid) soils increased the maize and wheat yields by 28 and 24% respectively at Palampur, by 19 and 12% for soybean and wheat crops

at Ranchi and by 6% for maize at Banglore whereas at Bhubneswar its significant effect was noticed only after 10 years increasing the kharif and rabi rice yields by 29 and 21% respectively. Lime application helped in improving and maintaining the pH value of soils at all the four locations.

FYM: Blending of organic manure FYM @ 10-15 per ha per year to the inorganic 100% NPK proved to be beneficial at all the locations giving the highest yield increase of 44 and 41% for maize crop at Palampur and Ludhiana, 27% for kharif rice at Bhubneswar, 23% for soybean at Ranchi and between 6 to 19% at rest of the locations and crops. Its residual effect on the succeeding crops was highest for wheat at Palampur (32%), for rabi rice at Bhubneswar (24%) and ranged between 5 to 19% at rest of the locations. Incorporation of FYM improved the soil fertility (N, P, K) in all the years at each of the locations.

Sulphur: Supplementing the optimal NPK through the fertilizers with sulphur content was effective for both the crops at Palampur and Jabalpur centres and for kharif rice at Barrackpore and Bhubneswar. The respective yields increase over the optimal level were 32% for maize and 24% for wheat at Palampur, 9% for soybean and wheat at Jabalpur, 26% for kharif rice at Barrackpore and 13% for kharif rice at Bhubneswar. Sulphur application did not contribute in raising the soil fertility at any of the locations.

150%NPK: Enhancement of the optimal NPK dose by 50% resulted with overall yield increase of 12% for both the crops at Ludhiana, 15 and 8% respectively for maize and wheat at New Delhi, 15% for both ragi and maize crops at Bangalore, 10% for both the rice crops at Bhubneswar, 22% for wheat and 11% for both rice and jute crops at Barrackpore centre. Enhanced dose of NPK did not result in any increase in the yields over the optimum NPK at Ranchi, Palampur and Coimbatore centres. Application of 150% NPK increased the build up of P in soils over those obtained at optimal NPK level at all the locations.

Under the project 'Combined analysis of experiments on long range effect of continuous cropping and manuring on soil fertility and yield stability', bivariate and over years analysis taking grain and straw yield of each cropping system have been done. Treatment response and variability in terms of grain yield and monetary returns for both the rabi and kharif seasons have been calculated. In some centres where yields were missing, the yields were interpolated by taking best fitted models.

At Rewa centre, in kharif season (1978-79 to 2003-04), Treatment T_{18} (N:P:K::120:80:40) was maximum productive giving highest mean grain yield as 41.23 q/ha followed by T_{17} (120:80:0) (mean grain yield=40.06 q/ha). Treatment T_{19} (Control) gave lowest mean grain yield (19.3 q/ha). But if one examines the consistency of the treatment responses, treatment T_{10} (80:40:40) was most consistent (C.V. =22.64) followed by treatment T_6 (40:80:40) (C.V. =23.29). T_{19} (Control) was most inconsistent treatment having C.V. = 30.35. In terms of monetary return, treatment T_{17} (120:80:0) gave maximum return (Rs. 11510.29) followed by T_{18} (120:80:40) (Rs. 11065.35). In rabi season treatment T_{17} was maximum productive having mean grain yield as 33.48 q/ha followed by T_{18} (30.06 q/ha), but if one observes the consistency of the treatment, T_3 (40:40:0) was most consistent followed by T_2 (40:0:40). In terms of monetary return, T_{18} gave maximum return (Rs.11270.23) followed by T_{17}.to remove/reduce the multi-collinearity among the explanatory variables (mean number of total tillers, mean number of ear bearing tillers/s.u., mean plant height in cm., mean number of grain/penicle, mean number of sterile spikelet/ panicle and number of days taken for 50% flowering) at Rewa centre, various methods like dropping variable, ratio approach and Ridge regression were attempted. Among all the methods, Ridge regression method has provided satisfactory results. The signs of the regression coefficients obtained by Ridge regression are theoretically plausible. Results showed that plant height is not significantly contributing to the grain yield whereas number of grains/panicles followed by number of ear bearing tillers/s.u. is significantly contributing to the grain yield.

To study the yield trends in relation to different soil characteristics viz. available N, P, K; pH and OC, soil data have been transcripted. For fitting different models SAS codes have been written and analysis has been completed. The results are being examined for the validity of the various fitted models. SAS codes for fitting response surface have been written to determine optimum doses of N,P and K at each location under study.

Statistical analysis of experiments on determining level and frequency of phosphorus application in different cropping systems revealed that for judicious use of Phosphorus, its application at the rate of 30 kg P_2O_5 per hectare applied in either season in alternate years might be economical. Under rice-wheat sequence application of 30 kg P_2O_5 per hectare at Banswara and

60 kg P_2O_5 per hectare at Palampur to both the crops in alternate years proved to be beneficial for higher returns and both these treatments were insensitive to the hange in the selected price ratios. At Varanasi and R.S. Pura, the maximum returns were obtained from 90 kg of P_2O_5 per hectare applied during kharif and rabi both every year which was sensitive to different price ratios examined. Under rice-gram sequence at Rewa, maximum returns were obtained with 60 kg P_2O_5 per hectare applied during kharif or rabi every year or during both the seasons in alternate years. This treatment was sensitive to the different price ratios tried. From pigeonpea-wheat sequence, at Rahuri the highest returns were obtained when 90 kg of P_2O_5 per hectare was applied to both the crops every year, whereas, at Bichpuri, its application at the rate of 30 kg P_2O_5 per hectare during kharif or rabi every year was observed to be the optimum. Application of P at the rate of 60 kg P_2O_5 per hectare to soybean crop followed by sorghum crop every year at Parbhani gave the maximum returns, whereas, when sorghum was replaced by sunflower and 30 kg P_2O_5 per hectare was given to either soybean or sunflower every year proved to be beneficial. Maize followed by soybean and pearlmillet followed by mustard gave the maximum returns when 60 kg of P_2O_5 per hectare was applied during kharif or rabi in alternate years and to both the seasons every year at Coimbatore and S.K. Nagar centres, respectively.

High cost-benefit ratio was observed when phosphorus was applied at the rate of 30 or 60 kg P_2O_5 per hectare during kharif or rabi in alternate years at different locations. The analysis further revealed that available nitrogen in the soil got depleted in all the plots at Navsari, Palampur, Rewa, Bichpuri, Coimbatore and S.K. Nagar. The available P content in the soil in all the plots increased over the cycles at Bichpuri and Rahuri whereas at Navsari and S.K. Nagar built up was observed only upto the first cycle and thereafter the soil got depleted in P. At Rewa, application of P could not enhance the P content of the soil which remained at the same level between 11 and 13 kg P_2O_5 per hectare throughout the experiment. The available K content in the soil increased only at Palampur and Coimbatore, whereas there was a marginal depletion in the available organic carbon in the soil at Rewa and S.K. Nagar.

Experimental Designs for Agricultural, Animal, Agroforestry and Fisheries Research

An agroforestry experiment 'Evaluation of fodder trees with and without crops under rainfed arable farming for semi-arid conditions' consisting of 4 tree species (siris, neem, shisham, babul) with 2 crops (gram and barley) giving rise to 14 treatment combinations (siris, siris+barley, siris+gram, neem, neem+barley, neem+gram, shisham, shisham+barley, shisham+ gram, babul, babul+barley, babul+gram, gram and barley) is being conducted at the collaborating centre (IGFRI, Jhansi) since 1999. The data on crops and trees are collected regularly. The crop data is analysed considering the four factors affecting the yield of the crops (trees, location of the trees in the plot, direction of the crop on the either side of the tree and distance of the crop from the tree). The data of the tree component from 12 treatment combinations is analysed as RBD with 2 replications. Contrast analysis technique is applied for identifying the significant factors. In kharif 2004, cowpea for fodder was introduced as a common treatment in all the 14 plots of the experiment.

The analysis of data on gram and barley for rabi 2004-05 has been performed separately considering five treatments (with four tree species and one without tree) in RBD with two replications. A significant difference has been observed between the control treatment (without tree) and other treatments. The analysis revealed that performance of the understorey crop was affected by the tree species and the distance of the crop from the tree base.

The cowpea data was analysed for all the characters as RBD with 14 treatments in 2 replications. The results showed a significant difference between the treatments for all the characters except plant population. The crude protein yield of stem and leaf of the tree component for the year 2004 from 12 treatment combinations (siris, siris+barley, siris+gram, neem, neem+barley, neem+ gram, shisham, shisham+barley, shisham+gram, babul, babul+barley, babul+gram) was analyzed along with the within group comparisons (4 groups from 4 tree species).

Further the data on growth parameters of four tree species with and without crop biomass yield (dry and fresh leaves) and crude protein were also analysed. The within group comparisons for crude protein showed that the crude protein yield was significantly different in case of groups containing babul indicating the effect of crops.

A series of circular neighbour balanced complete block designs for agroforestry experiments with *v* levels of tree and *v-1* levels of crop balanced for tree effects

have been obtained using a complete set of mutually orthogonal latin squares. The *v(v-1)* combinations of factor T (tree) and C (crop) have each of the levels of factor T as left and right neighbour once.

The coefficient matrix of the reduced normal equations for estimating the effects of *vn* factorial treatment combinations arising from *v* treatments and *n* experimental units has been derived using calculus for factorial arrangements considering a balanced uniform class of repeated measurements designs (RMDs) with a pre-period (treatments in the pre-period are same as those in the first period and no observations are taken from these treatments) under a non-additive model set up. Also, computer programs have been written for obtaining joint information matrix of direct and first residual effects and information matrices, separately, for direct effects and first order residual effects, for a given RMD. Computer program has been written for simulating RMD data under an additive fixed effects model considering direct and residual effects of treatments, period effects and unit effects as fixed and error effects as random. Also, computer program has been written for generating RMD data under mixed effects model, where direct, residual and period effects are treated as fixed and unit and error effects are treated as random. Program has been written for simulating RMD data under a non-additive model considering direct, residual and period effects as fixed effects and unit and treatment × unit interaction effects as random effects. Assuming AR1 correlation structure among observations, computer program has been written to simulate RMD data. Again, SAS programs have been written to estimate variance components of random effects under mixed model set up of RMD by using different methods like ML, REML, MIVQUE0. Another program has been written in WINBUGS to estimate treatment effects in a 2×2 repeated measurements design without residual effects.

In the case of multiple outliers, a well-known problem known as 'masking' hinders the identification problem. In masking, effect of one outlier is masked by the presence of another outlier, hence cannot be detected as outlier if we apply single outlier detection procedure. A new statistic was developed for tackling the problem of masking. The developed statistic was applied to experimental data from AFEIS. It was found in some experiments that individually some observations were not influential, but jointly with some other observations, they are influential, that is, some observations were masked by some other outlying observations and therefore, were not detected when we apply single diagnostic procedure. Robust methods for data analysis were thoroughly reviewed. A number of robust techniques are available in the literature for analyzing data generated by linear regression models. These techniques are explored for application into designed experiments. A robust regression procedure is one that dampens the effect of observations that would be highly influential if least squares were used. That is a robust procedure tends to leave the residuals associated with outliers large, thereby making the identification of influential points much easier. The motivation for much of the work in robust estimation was due to Huber (1964). One of the most popular robust methods is M-estimation. A good number of objective functions to be minimized are proposed. To begin with Huber's t-function has been applied to experimental data obtained from "Agricultural Field Experiments Information System (AFEIS)". Relevant computer programs are written.

The usual method of analysis requires that the errors in the observations are independently and normally distributed with constant variance. In the situations when errors are likely to be correlated, it is desirable to obtain designs and perform analysis in which the correlations are taken into account. If the observations are adequately modeled, it is expected that there will be increase in precision. The knowledge of correlation structure is advantageous in planning the experiment. In case of block design, it is assumed that there is no between-block dependence, and that the within-block dependence between plots is the same in each block. Nearest neighbour correlation structure, first order autocorrelation structure and equi-neighbour correlation structure have been considered.

A block design is called pairwise uniform on the plots if each treatment i, (i =1,...,v) occurs equally often in each plot position l, (l=1,...,k_j) and each pair of treatments i and i', $i \neq i'$ (=1,...,v) occurs equally often (λ_{ii} times) within the same block in each unordered pair of plot labels l and l', $l \neq l'$(=1,...,k_j) and a pairwise uniform design, whenever existent, is universally optimal.

A method of construction of universally optimal pair-wise uniform incomplete proper block design has been obtained for even block size through the initial block solution.

A SAS code using PROC IML has been made to

obtain the information matrix of a block design for a given correlated error structures with specific value of correlation coefficient.

Combining the blocks of p equi-neighboured balanced block design in v treatments with block size k_m (m=1,2,...,p) would result in a equi-neighboured balanced block design with unequal block sizes.

Methods of constructing equi-neighboured balanced block designs with unequal block sizes in lesser number of units is being attempted. Development of some methods of construction of row-column designs to guard against the effects of correlated observations, possibly with minimum number of experimental units is being explored.

PROGRAMME 2: FORECASTING AND REMOTE SENSING TECHNIQUES AND STATISTICAL APPLICATIONS OF GIS IN AGRICULTURAL SYSTEMS

Developing Remote Sensing Based Methodology for Collecting Agricultural Statistics in Meghalaya

The study is in collaboration with Space Application Center (SAC), Ahmedabad and North Eastern Space Application Center (NE-SAC), Shillong.

The basic aim of this project is to develop a survey methodology for estimation of crop area and crop yield in Meghalaya using Remote Sensing and GIS. The main problem of hilly regions is its undulating topography and non-accessibility of vast area. Further, the relative percentage area under the crops is also less. The remote sensing satellite data alone with conventional approach used till date may not be applicable to this type of regions for retrieving crop information due to these reasons. Therefore, major concern till date is to use satellite data supported with ground survey data for reliable estimation of the above parameters. In this project development of statistical methodology to tackle such problem is attempted. In the absence of any satisfactory objective technique for crop acreage and production estimation, the present study has been divided in two phases. In the first phase, pilot study was conducted in one district of Meghalaya for estimating area under paddy. In the second phase to test and validate the methodology developed during the first phase the study has been repeated in the same district and another new district.

The satellite data of IRS-1D, LISS-III sensor is used for district Ri-bhoi and that of IRS-1D, LISS-III and IRS-P6 LISS- III was used for the district of Jantia Hills. The satellite data was rectified and classified using Maximum Likelihood supervised classification technique in ERDAS Imagine software. Survey was conducted along the major roads of both the districts. A buffer of 250 m was generated along both sides of the road in GIS environment using ARC GIS software. To obtain a reliable estimate of area under paddy along a buffer of 500 meter, the roads are conceptually divided into segments of 500 m. A sample of segments is selected randomly on each of the road and a grid of 500 x 500 m^2 has been observed for recording the area under paddy which was measured by Global Positioning System (GPS). The area under paddy crop in these selected grids was also recorded by eye estimate. Huge data was collected during the survey. Regression analysis was performed to develop relationship between the eye estimates and GPS readings. Suitable estimators for area under paddy crop, for both the districts, were developed using the estimate obtained by road survey, classified image. Besides this, various methods of estimation like ratio estimators, grid based sampling etc. were used to estimate the paddy area covered by clouds/cloud shadows in the image.

The area estimated under winter paddy crop for Ri-Bhoi district is 7506 ha with a standard error of 1.93% for the year 2005-06. First-cut estimates of winter paddy area in Jantia Hills district based on image analysis and GPS correction was about 8000 ha. But, corrections made for missing data (due to coarse resolution of the sensor, hill shadow etc.) gave an estimate of 5956 ha. The study will be extended for more crops and more districts will be covered in future.

Assessment of Survey Capabilities of Private Sector Methodology

The study sponsored by Ministry of Statistics and Programme Implementation for evaluating survey capabilities of private sector is based on assigning scores to the various measurable indicators developed for the purpose. The indicators are based on the items on which information is collected through the questionnaire followed by physical verification of the items in the filled-in questionnaire. Broadly, five types of indicators are considered, Projects handled in the past, Manpower, Infrastructure, Experience and expertise, and Annual turn-over on survey related activities.

Besides this every agency need to meet the basic eligibility criteria (which are non-negotiable) before it

can be considered for inclusion in the database such as should have a PAN number, using probability sampling design, one statistician on regular basis, and connectivity in any of the three ways namely Telephone, Fax, E-mail. The survey agencies satisfying non-negotiable criteria would be listed. Based on the importance of each indicator type, the weight would be assigned for working out overall score of the survey agency.

A study on editing and imputation using Neural Networks is undertaken with ultimate objectives as to examine the performance of artificial neural network technology for editing of statistical records, to investigate the accuracy of imputing missing values using neural network and hot deck imputation procedure, and to develop software for the imputation of missing data.

The back propagation algorithm for imputing the missing data is complete. It was developed in command line interface in Java to test the working. Now it is implemented in graphical user interface using Java Swing. The model is predicting the missing data after the training of model. The system is using Java technology, it is platform independent. Different options in entry form has been done like cut/copy/paste, sort by category. The software development module for zero imputation is complete. Hot deck and mean imputation is being done.

PROGRAMME 3: DEVELOPMENT OF TECHNIQUES FOR PLANNING AND ANALYSIS OF SURVEY DATA INCLUDING ECONOMIC PROBLEMS OF CURRENT INTEREST

An Econometric Approach for Measurement of Indemnity and Premium Rates under Crop Revenue Insurance

The study is undertaken with objectives as (i) to examine the sources of instability for identifying critical variables for Crop Revenue Insurance, (ii) to estimate indemnity and premium rate of selected crops in different states of India for Crop Revenue Insurance, and (iii) to explore the feasibility of Revenue Insurance approach vis-à-vis Yield Insurance approach in Indian agriculture.

To measure the instability of economic variables (area, yield and price), Cuddy-Della Valle index (corrected coefficient of variation) is used which takes into consideration the long-term trend.

Premium rates have been estimated with the help of existing yield approach methodologies for different crops of various districts of Karnataka state. Data sets have been subjected to normality test wherever required. Premium rates were calculated by the normal curve technique with some exceptions indicating for the instability in the yield for that particular crop. For the nonparametric kernel approach, the window width has been estimated which are found in the range of 120 to 230. The premium estimation under crop revenue insurance using gross return in lieu of yield is also taken up.

Dietary Pattern and Nutritional Status of Rural Households: State wise Analysis

The objectives of the project are (i) to study the change in dietary pattern and nutritional status of different socio-economic groups of rural households due to change in economic environment, (ii) to identify the socio-economic factors influencing the dietary pattern and nutritional status of rural households and (iii) to identify the target groups for prioritization for improving the nutritional status.

The study showed that in 55th round (1999-2000) over 43rd round (1987-88), the dietary pattern of rural households, in almost all states a general trend of reduction was observed in consumption of cereal in favour of non cereal foods. The consumption of other non cereal foods like milk and milk products, egg, meat and fish, fruits and vegetables groups tend to increase in most of the states. However the shift from cereal based to non cereal based diet was not visible in all categories of socio-economic groups uniformly. An effort was also made to study the rural households deficient in important nutrients including important vitamins and minerals. It was observed that the proportion of deficient households in different nutrients varied from state to state and among categories of landholdings. In most of the states the proportion of deficient rural households was higher in landless, sub-marginal and marginal class and it decreased with the size of holdings. This showed that the balanced diet was not only dependent on expenditure of food items but also depended on the dietary pattern and the choice of the foods. It was observed that Assam and Orissa were the most deficient state in most of the nutrients. Punjab and Haryana were at a better situation in terms of nutrients intake in the diet.

The analysis of determinants of nutritional status showed that in most of the states and land holding categories of rural households the key factor influencing

nutritional status was per capita expenditure on food. In all the states the coefficients of unit calorie cost and non-food expenditure were found negative and significant at 1 percent of level of significance indicating that higher prices of food items and excess expenditure on non-food items affected the nutritional status of rural households adversely. In most of the cases coefficient of education level was not found significant. In some cases the coefficient of education level was positive and significant indicating the positive impact of education on nutritional status while in some cases it was also found negative and significant indicating that either due to lack of knowledge about nutritive values of various kinds of foods or the selection of food items based on traditional or taste based and not knowledge based. In most of the cases the coefficient of household size was found to be negative and significant which indicated that bigger the family size the lower the nutritional status of the household.

The analysis suggested that the landless, sub-marginal and marginal category of households in most of the states should be treated as target groups to raise their income to maintain their nutritional status.

Study of Lac Marketing in India

The study on "Lac Marketing in India" was undertaken with a view to provide a practical solution of the problem of declining trend in total lac production in the country during past decades. Accordingly an integrated approach was adopted where the three aspects namely Lac cultivation, Lac marketing and Lac processing was examined in the major producing states of Jharkhand, West Bengal, Chhattisgarh, Madhya Pradesh and Maharashtra by primary survey data.

Lac Cultivation: Palas tree was identified as the major lac host in all the producing states and minor hosts were Ber and Kusum trees. The extent of lac host exploitation of the major host tree was observed to be about 50 percent in almost all the states despite of attractive returns from lac cultivation. This is the critical factor which is responsible for low crop production. The study of constraint analysis was carried out to find out possible factors for low production. The correlation coefficients obtained among the identified constraints revealed the shortage of funds to purchase critical inputs like brood lac is the most important factor. Principal Component Analysis using extraction method, however, suggested shortage of owned funds, non-availability of cheap credit and distance of lac host from home (guarding) are the important factors for low production.

Lac Marketing: The crop output i.e. scrap lac is mainly sold in the village/local markets. The marketing channels identified in the study are

Channel- I	Lac Cultivator to Primary Purchaser
Channel- II	Primary Purchaser to Wholesale Purchaser
Channel- III	Primary Purchaser to Local Processing Unit
Channel- IV	Wholesale Purchaser to Wholesale Market

The pattern of marketing is area specific, in the areas where local processing units are situated bulk quantity of scrap lac is supplied to them by the primary purchasers and little quantity is sold to wholesale purchasers. The wholesale purchasers sold their major part of scrap lac in the wholesale market and little quantity to the processing units.

The marketing cost computed for different markets ranges between Rs. 0.35 to Rs. 0.88 per kg depending upon the location of the market. The major items of marketing cost are cost of jute bag (about 50 percent), transportation cost (about 30 percent) followed by loading/un-loading charges, weighing charges and market fees etc.

The nature of price spread or share of each channel in the profit earned in marketing largely depends upon the pattern of marketing. In the areas where bulk of the quantity is sold to the processing units major share in rupee profit is earned by primary purchasers otherwise the whole sale purchasers have significant profit sharing.

The regression estimates of Price Spread Model are obtained using retail price, wholesale price, product of quantity traded & retail price and time (week) as influencing variables. All the independent variables except for product of quantity & retail price significantly influenced price spread in most of the markets. Bivariate market co-integration analysis suggested that lac markets located at distant places are weekly co-integrated.

Lac Processing: Lac processing units situated in Chhattisgarh, Maharashtra, Jharkhand and West-Bengal were surveyed. The average number of labour employed in the units varied between 14 to 18 per shift. The processing unit produced mainly Shellac, Seedlac and Button lac. The response of the processing units for the declining trend of total output revealed that demand of output was not constant because it was largely governed by export demand. The violent fluctuation in scrap lac prices affected crop production.

Agricultural Research Data Book 2005

Agricultural research is a vital input for planned growth and sustainable development of agriculture in the country. The Council being an apex scientific organisation at national level, plays a crucial role in promoting and accelerating use of science and technology programme relating to agricultural research and education. It also provides assistance and support in demonstrating the use of new technologies in agriculture.

Information pertaining to agricultural research, education and related aspects available from different sources is scattered over various types of published and unpublished records. The Agricultural Research Data Book 2005, which is ninth in the series, is an attempt to put together main components/indicators of such information. The Data Book comprising of 240 Tables, is organized for the purpose of convenience of the users into eleven sections namely, Natural Resources, Environment, Agricultural Inputs, Fisheries, Horticulture, Production and Productivity, Produce Management, Export & Import, Indian Position in World Agriculture, Investment in Agricultural Research & Education and Human Resources under National Agricultural Research System (NARS). It also contains at the end, list of important National and International Agricultural Research Institutions associated with agricultural research and education along with their addresses, telephone numbers and e-mail addressses. The Data Book has been compiled through the joint efforts of the Indian Agricultural Statistics Research Institute (IASRI) and Indian Council of Agricultural Research (ICAR). This edition contains the latest information/ data as available in the country at the end of April, 2005. Accordingly, the Agricultural Research Data Book 2005 was published and released by the Hon'ble Union Minister of Agriculture during the 76th Annual General Meeting of ICAR, held at NASC Complex, New Delhi on 15 July, 2005. It was distributed among the members of the Governing Body, senior-level officers of the Council, Vice-Chancellors of SAUs, Directors of ICAR Institutes and other senior level officials under NARS as well as other organisations.

The preparation of Agricultural Research Data Book 2006 is under process.

PROGRAMME 4: MODELLING AND SIMULATION TECHNIQUES IN BIOLOGICAL SYSTEMS

A study entitled "Statistical investigation on the performance of non-parametric stability measures when the genotype × environment data is non-normal" was taken up with objectives as to statistically evaluate the merits of different non-parametric stability measures when the basic data/variables are non-normal, compare the performance of non-parametric measures with parametric measures under the non-normal situations, and to explore the possibility of developing new measures of stability/simultaneous selection measures.

Type-1 errors and the power for different nonparametric stability measures in case of normal as well as non normal distributions, gamma and log normal for different combinations of genotypes and environments *i.e.* genotypes 8, 12, 16, 20, 24 and environments 5, 10, 15, 20 are obtained for given values of level of significance *i.e.* .01, .025, .05 and .1.

Simulation was also done for different stability measures in case of Weibull distribution according to the value of shape parameter c of Weibull distribution. If $c < 3.602$ the distribution has a long right tail. If $c = 3.602$, it closely approximates to normal. If $c > 3.602$ it has a long left tail. The results so far obtained revealed that three measures are showing good performance in terms of power of the test.

Some Investigations on Stable and Robust Clustering Procedures was undertaken with the aim to study exhaustively and critically the important clustering methods which are being used in most emerging fields in agriculture and allied sciences, to simulate several multivariate normal populations for investigating the performance of commonly used clustering procedures, to develop suitable technique for obtaining stable and representative clusters, to identify stable and robust clustering procedures especially for missing data situations, and to evaluate the performance of the clustering procedures so identified on real data.

Samples of small size 25 for tall, medium and dwarf rice varieties were generated with the help of estimated mean vectors, dispersion matrices through SAS program developed for this purpose. Percentage misclassifications were compiled, calculated and tabulated for different combinations of clustering methods and distance measures under total nine variables as well as on different combinations of selected variables. The percentage misclassifications were calculated under two methods of standardization viz. z-score of variables and range of variables. The whole percentage misclassifications were brought together by providing different codes against method-distance combinations, clustering methods, distance measure, Z-scores and range of variables for the further

analysis in order to draw inference on the spitted data set. In order to validate its performance over large sample size, three samples each of size 100 have been generated from specified multivariate normal population and have been mixed for carrying out further study.

Effect of selection and incomplete model specification on heritability estimates was taken up to catalogue different methods of estimation for heritability with respect to selection pressures, to identify different procedures of estimation of heritability in the presence of non-normality and abnormal observations, and to study the effect of incomplete models on the heritability estimates.

The identification of different methods for studying precise estimation of genetic variance components has been taken up. The work on simulation of populations having effect of the selection as well as incomplete model specification has also been taken up. The bias of the estimates of heritability have been examined under different situations.

PROGRAMME 5: DEVELOPMENT OF INFORMATION TECHNOLOGY IN AGRICULTURAL RESEARCH

Under the Institute project 'Development of Statistical Package for Animal Breeding 2 (SPAB2)' six modules as per RPF-I were developed. These modules were thoroughly tested and their workings in the window environment were examined. In addition, some general class modules like, Matrix inversion, Matrix and Vector multiplication, Vector multiplication, Floating number printing and calculation of probability for F test have also been developed.

Under the Institute project 'Development of Expert System on Wheat Crop Management' four modules viz. variety selection, plant protection, cultural practices and harvest have been developed and ensured its smooth working. In addition to these two separate sub modules for wheat machinery and for data management have been developed and integrated with the system. The data management module takes care of data entry for all the modules and helps in addition, updating and deletion of data and in creation, updating and deletion of rules for the expert system. Multimedia effects have been added to the system. It guides the user with its voice for identification of disease, insects and weeds.

An AP Cess funded project 'National Information System on Agricultural Education Network in India (NISAGENET)' was started to develop a database management system that will provide the required information. The sensitization, feasibility and requirement analysis have been carried out by conducting different workshops at various State Agricultural Universities and Research Institutions.

Under the project development of 'Software for the Analysis of Survey Data' the object oriented programming concepts on the language C++ with added advantages of the latest .NET Technology are being used. The Data management module of the application software has the features of creating and saving a new data file with all data editing tools in spreadsheet form. It can also import data from already existing files, which are either from MS-Excel text files, or MS Access database files. Coding for imputation techniques for the missing data has also been done for Imputation Module. Imputation of missing data has been given with three different options namely Zero imputation, Mean imputation and Mean of the neighbouring units. The module also takes care of imputation within the sample data; within the sample from the defined stratum, within the sample from the defined cluster as well as within the sample from the defined stratum and clusters both.

A new institute project 'Development of PERMISnet-II' has been initiated from 01 July 2005 with the objectives to maintain and strengthen the PERMISnet system, to add new modules/reports as per the manpower planning requirements and to design and develop the software PERMISnet-II with .NET framework.

Information System for Agricultural and Animal Experiments

New web-enable software for Agricultural Field Experiments Information System (AFEIS) has been developed and is now available at IASRI website. The system caters to four types of users viz. **Un-registered users** - who can access the reports developed to give a flavour of vast information and create an interest to view details by getting registered with the system. **Registered Users** - who can generate reports by making choice on one or more of important characteristic of experiment and can view the details of the desired experiment. **Administrator** - who can update and validate the database and view the reports. **Super Administrator** - who has overall controls of the database and has right to update the status of other users.

Some of the salient features of the system are:

a. Users can build/automate their queries about agricultural experiments based on location (state), research station, crop, season, soil type, factors, agro climatic regions and crop group etc.
b. The details of each experiment have been divided into eight divisions and each division into several data items. The system provides choice to user to view experiment in full or a part thereof (division) as per his interest. Attempt is being made to provide the user with analysis of data, wherever plot-wise data is available.
c. From administrator's point of view several forms for on-line data entry have been developed.
d. The system has details of about 20,000 experiments.

National Information System on Long Term Fertilizer Experiments

National Information System on Long Term Fertilizer Experiments has been developed to store and maintain the data generated under long term fertilizer experiments in progress/concluded at various organizations under the Horticulture, Crop Sciences and NRM divisions of ICAR.

It is a user friendly web-based information system for on-line data entry and retrieval of information of long term fertilizer experiments and has been developed with Java Server Pages at front end and Structured Query Language Server at back end and has been hosted on website of IASRI http://www.iasri.res.in:8081/nisltfe.

The Home Page of the NISLTFE consists of five modules viz. (i) Introduction, (ii) Data Management module, (iii) Reports module, (iv) Contact Us module, and (v) Help.

The Data Management module handles the on-line data entry and updating tasks for experiment related information through a number of forms. The system provides a login form as a security barrier before entering into the module. Only the authorized users (System Administrators/Nodal Officers) of the system can enter into the Data Management module after entering their user Id and password.

The Reports module handles the information retrieval tasks from the database and its display to the user. The reports are both of fixed and user-customized type. Different types of users would be able to generate reports of their own interest in a proper and structured manner. However, the Guest User would not be allowed to view character-wise experiment data value reports. For this the guest user will have to secure an Id and password from any of the persons under Contact Us module. The reports option form provides the user with various options for generating different types of reports viz. Help in the form of User manual has also been provided for accessing various modules and how to enter, update and retrieve the information from the information system.

PROGRAMME 6: TEACHING AND TRAINING IN AGRICULTURAL STATISTICS AND COMPUTER APPLICATION

Another important activity of the Institute is to impart education and to conduct post graduate and in-service training courses in Agricultural Statistics and Computer Application. The achievements made under this programme are outlined separately under Education and Training.