



Professor VK Gupta's Influence on Design of Experiments and Sample Surveys

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Abstract

Professor V. K. Gupta has made notable contributions in Designing of Experiments that includes obtaining efficient and robust designs for various experimental settings *viz.* block designs; row-column designs; block designs with nested factors; designs for making test treatments-control comparisons; designs for diallel crosses; designs for bioassays; crop sequence experiments; interference effects; correlated error structures; fractional factorial plans, supersaturated designs; computer aided search of efficient designs for many experimental situations and for many practical ranges of parameters; shape and size of plots and blocks, diagnostics in designed field experiments; intercropping experiments; experiments with split application of inputs, *etc.* He has also made use of the combinatorics in sample surveys and because of this he has made several original contributions to the theory of survey sampling, particularly variance estimation from large scale complex survey data, unequal probability sampling, controlled selection and balanced and distance balanced sampling plans. He has also worked on calibration approach of estimation of parameters. In this manuscript, a valiant attempt shall be made to highlight briefly few prominent results from the above.

Key words: Design of experiments; Sample surveys; Optimal designs; Robust designs.

AMS Subject Classifications: 62K05, 05B05

1. Introduction

Professor V. K. Gupta (VKG) was born in Bombay, India, on March 17, 1951. He joined Indian Agricultural Statistics Research Institute (IASRI) [the then Institute of Agricultural Research Statistics (IARS)] in 1970 as M.Sc. student in Agricultural Statistics followed by P.G. Diploma in 1974. He started his academic journey during May 1974 from Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Hisar [the then Haryana Agricultural University (HAU)] and was there till December 1974. He joined ICAR-IASRI in 1975 and superannuated in March 2016 as National Professor at the age of 65 years. Now he has completed 55 years of his Journey in the discipline of Statistics.

Describing the work done by him is showing lamp to the bright sun. But still, I am tempted to take this chance.

2. Academic qualifications

VKG got his school education at Delhi United Christian School, Delhi, and completed his senior Secondary in 1967. After completing B.Sc. from Ramjas College, University of Delhi in 1970, he joined IASRI (then IARS) as M.Sc. student in 1970 and completed his M.Sc. in 1972. During his M.Sc. he worked on **Study on efficiency of systematic sampling in estimating lactation yield of a cow** under the guidance of Sh. M. Rajagopalan. It was followed by P.G. Diploma in Agricultural Statistics in 1974 during which he worked on **Some empirical studies on estimation procedures in sample surveys on minor crops** under the guidance of Dr. A.H. Manwani. He completed his Ph.D. (Agricultural Statistics), as in-service student and submitted his Ph.D. thesis on the topic **Use of combinatorial properties of block designs in unequal probability sampling** in less than 2 years under the able guidance of Professor A. K. Nigam.

3. Professional career

VKG began his professional career in 1974 at HAU Hisar (now known as CCS HAU, Hisar) as Assistant Statistician. He then joined Institute of Agricultural Research Statistics (IARS) [now known as ICAR-IASRI] as Statistical Investigator in 1975. In 1976, Agricultural Research Service (ARS) was initiated by Indian Council of Agricultural Research and after passing the ARS Examination, he joined IASRI as Scientist S-1 in the first batch of ARS in August 1976. In 1982, he was promoted to Scientist S-2, which was re-designated as Senior Scientist in 1995. He coordinated the teaching activities of discipline of Agricultural Statistics with PG School, Indian Agricultural Research Institute (IARI) as Professor (Agricultural Statistics). Based on his significant research contributions, he was awarded the position of ICAR National Fellow in 1995. Perhaps he was the first ICAR National Fellow in the discipline of Agricultural Statistics (1995-2000). After 2000, by now four other Agricultural Statisticians (Rajender Parsad, Hukum Chandra, Ranjit Kumar Paul and Eldho Varghese) have received ICAR National Fellow Position. He has also contributed significantly to research management as Head, Division of Design of Experiments during 2000-2003 and Joint Director during 2003-2006 at IASRI (now known as ICAR-IASRI). He was invited by FAO as Consultant in 1994 in Beijing to design experiments for balanced fertilizers, a topic of global concern at present. He brought laurels and recognitions to the discipline of Agricultural Statistics in 2006 when he was awarded the position of ICAR National Professor for the first time to any Agricultural Statistician. He nurtured the school of Design of Experiments as ICAR National Professor, the position from which he superannuated on March 16, 2016.

4. Alma mater

ICAR-IASRI, New Delhi is a premier Institute of relevance in Statistical Sciences (Statistics, Computer Applications and Bioinformatics) and their judicious fusion in agricultural sciences for enriching quality agricultural research and informed policy decision making. It is in 10th Decade in the service of Nation [(a) 96 years in Agricultural Statistics: 1930 Statistical section in then ICAR; (b) 61 years in Computer Applications: 1965 ~ Installa-

tion of ICAR's first computing facility-IBM-1620 Data Processing System: All Statistical Analysis of data from National Agricultural Research and Education System (NARES) was done at ICAR-IASRI; and (c) 16 Years in Agricultural Bioinformatics: 2010 Establishment of National Agricultural Bioinformatics Grid].

ICAR-IASRI started its journey as a Statistical Section in 1930 in then Imperial Council of Agricultural Research and has grown to a premier institute of relevance to conduct research, education and training in the field of Statistical Sciences (Statistics, Computer Applications, and Bioinformatics). The Institute is mainly responsible for conducting research in Agricultural Statistics and Informatics to bridge the gaps in the existing knowledge. The Institute is using the power of Statistics, as a science, blended with Informatics and their judicious fusion in agricultural sciences for enhancing quality agricultural research, to meet the challenges of agricultural research in newer emerging areas and evidence-based policy decision making. The Institute also conducts M.Sc. and Ph.D. degree programmes in Agricultural Statistics, Computer Applications and Bioinformatics in collaboration with the Graduate School, ICAR-IARI, New Delhi. The Institute organizes customized and sponsored training courses in Agricultural Statistics and Informatics at National and International level to be a leading Centre of excellence in Human Resource Development. The Institute provides advisory and consultancy services for strengthening the National Agricultural Research and Education System (NARES) and undertakes sponsored research and consultancy for National and International organizations. The methodological support is provided in strengthening National Agricultural Statistics System (NASS). The Institute has also been playing a lead role in development of robust Agricultural Knowledge Management Systems and artificial intelligence-based applications for NARES. The present mandate of the ICAR-IASRI and major activities are

Mandate	Major Activities
• Research, education and training in agricultural statistics, computer applications in agriculture and agricultural bioinformatics. • Advisory / consultancy services / methodological support / computational solutions to NARES/NASS.	• Developing Statistical methodologies / techniques to support agricultural research and development. • Developing, supporting and maintaining Portals / Information-Management-Systems / Mobile Apps <i>etc.</i> and digital solutions for agricultural research and development. • Accelerating agricultural OMICS research in India through Network Project on Agricultural Bioinformatics and Computational Biology. • Capacity building in terms of M.Sc. and Ph.D. students in Statistical Sciences and knowledge updating of research fraternity through customized training programmes.

Stakeholders of ICAR-IASRI include Students, Scientists, Government Officials, Farmers. Throughout his professional career, VKG has been at his alma mater for 45+ years (more than half of 86 years journey of IASRI till 2016).

5. Awards and honours

VKG's monumental contributions have brought him many laurels, and he has been decorated with several awards like IARI Best Teacher Award 1999; First D. N. Lal Memorial Lecture award 2000 from Indian Society of Agricultural Statistics (ISAS); Prof. P. V. Sukhatme Gold Medal Award 2005 from ISAS; "Sankhyiki Bhusan, 2010 from ISAS", *etc.* He is an elected member of the International Statistical Institute; Elected Fellow of the National Academy of Agricultural Sciences (NAAS) and Fellow of the ISAS. He has been the Chair Editor, (i) Journal of the Indian Society of Agricultural Statistics during 2005-2012; and (ii) Statistics and Applications 2020-2025 and now Editor-in-Chief till date; Associate Editor of Journal of Statistical Planning and Inference; at present he is an Associate Editor, Journal of Statistical Theory and Practice and Agricultural Research. He is associated with many Professional Societies. He has been Sessional President, 61st Annual Conference, ISAS, 2007; Vice-President of Indian Society of Agricultural Statistics; Vice-President of Forum for Interdisciplinary Mathematics. Presently he is the President-in-Chief, Society of Statistics, Computer and Applications. He has also served as Editor, National Academy of Agricultural Sciences during July 2015 to December 2016.

6. Human resource development

VKG has been an outstanding teacher who took keen interest in Human Resource Development. He has taught several courses, which include Statistical Methods; Statistical Inference; Sampling Techniques; Design of Experiments; Linear Models, *etc.*; conducted a large number of ad-hoc Training Programmes under the aegis of Centre of Advanced Faculty Training, Summer/Winter Schools, for All India Coordinated Research Project on Energy Requirement in Agricultural Sector.

He has produced 50 (37 Ph.D. and 13 M.Sc.) students as Chairman/Co-Chairman Advisory Committee. These 50 students include 10 Ph.D. and 3 M.Sc. Students as Chairman Advisory Committee; 27 Ph.D. and 10 M.Sc. students as Co-Chairman Advisory Committee. A total of 42 distinct (08 both M.Sc. and Ph.D.) students have been mentored by him. Dr. Praggya Das is the first Ph.D. student guided by him as Chairman, Advisory Committee. Other 09 students guided by him as Chairman Advisory Committee are Drs. A. Dhandapani, Archana Pandey, D.V.V. Ramana, L.M. Bhar, Krishan Lal, J.S. Dhekale, Abhishek Rathore, Subhra Sarker, Subrata Kumar Satpati. Out of these Archana Pandey, D.V.V. Ramana, L.M. Bhar were also guided by him as Chairman Advisory Committee during their M.Sc. degree. He was also Co-Chairman Advisory Committee of Subrata Kumar Satpati. The other 32 students include

Sl. #	Name of Student	Degree
Co-Chairman (Chairman advisory Committee senior / colleague)		
1	Amitava Dey	Ph.D.
2	Ashish Das	Ph.D.
3	Cini Varghese	Ph.D.
4	Dileep Panda	Ph.D.
5	K. Venumadhav	Ph.D.
6	K. V. Palanichamy	Ph.D.
7	N. S. Gandhi Prasad	Ph.D.
8	Niti Agarwal	Ph.D.
9	P. K. Batra	Ph.D.
10	P. P. Yadav	Ph.D.
11	Priya Kohli	Ph.D.
12	Rajender Parsad	Ph.D.
13	Rajeshwar Singh	Ph.D.
14	Rama Krishna Singh	Ph.D.
15	Sanjay Dwivedi	M.Sc.
16	Seema Jaggi	M.Sc.
17	Somy Kuriakose	M.Sc.
18	Vijaya Raghava Kumar	Ph.D.
Co-Chairman (where Chairman, Advisory Committee is His students)		
19	Ajeet Kumar	Ph.D.
20	Ananta Sarkar	Ph.D.
21	B. N. Mandal	M.Sc., Ph.D.
22	Bishal Gurung	Ph.D.
23	Dinesh Pateria	Ph.D.
24	J. S. Tomar	Ph.D.
25	Jawaid Ashraf	M.Sc.
26	Pradip Nandi	M.Sc.
27	Ranjit Kumar Paul	M.Sc.
28	Sanklap Ojha	M.Sc.
29	Sarika	M.Sc., Ph.D.
30	Shashi Sekhar	M.Sc., Ph.D.
31	Sukanta Dash	Ph.D.
32	Susheel Sarkar	M.Sc., Ph.D.

VKG's students are working in academic, research and private organizations across the globe such as Former Director, Head of Divisions, National Fellow; Assistant Director General, ICAR; Scientists at ICAR Institutes; Faculty at State Agricultural Universities; Senior Researchers at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) / International Maize and Wheat Improvement Center (CIMMYT); Professor at Indian Institute of Technology (IIT); Vice-Chancellor Management Institutes; Deputy Director General, Ministry of Statistics and Programme Implementation, Govt. of India; Advisor-in-Charge Monetary Policy Department, Reserve Bank of India; Professors in US Universities including SUNY Distinguished Professor; Senior Statisticians in Pharmaceuticals; HP, GENPact, Tata Consultancy Services, Banks, *etc.*

7. Significant contributions in design of experiments and sample surveys

During his long stint at ICAR-IASRI, VKG has made important and useful research contributions to both theoretical and applied aspects of Agricultural Statistics in general and Design of Experiments and Theory of Survey Sampling in particular. He has made outstanding theoretically creative and methodologically innovative contributions in the development of the subject of Statistics and its applications in the NARES. He always paid attention to the most challenging problems and came up with ingenious ideas that enhanced our understanding significantly. It is nearly impossible to describe all the research contributions of VKG in a limited space, and so, in what follows only a few examples of his major contributions are provided.

In an International Conference on Statistics and Informatics, organized by VKG as Organizing Secretary in 2006, Dr. M. S. Swaminathan in his written message said “*It is the effective use of the tools of statistical design of experiments that paved the way for the green revolution.*”

VKG has handled 25 research projects including ICAR National Fellow Scheme on ‘**Studies on Optimality of Designs Useful in Agricultural and Animal Experiments**’ (1995-2000); ICAR National Professor Scheme ‘**Designs for Single Factor and Multi-factor Experiments and their Applications in Agricultural Systems Research**’ (05.04.2006-16.03.2016) and externally funded projects from agencies like ICAR AP-Cess Fund, Department of Science and Technology (DST), Food and Agriculture Organization of the United Nations. In a FAO sponsored project, he has also contributed towards development of methodology for estimation of crop area and crop yield under mixed and continuous cropping.

7.1. Design of experiments

Some of his many notable contributions in design of experiments include obtaining optimal/efficient designs for various experimental settings *viz.* designs for making all possible pairwise treatment comparisons, designs for making test treatments-control comparisons, designs for diallel and tetra-allel crosses, block designs with nested factors, structurally complete/incomplete row-column designs, designs for bioassays, on-farm research, crop sequence experiments, estimation of competition effects, spatially correlated error structures, orthogonal fractional factorial plans, supersaturated designs and designs for microarray experiments. He has also significantly contributed towards investigating robustness of designs against several disturbances like loss of data, presence of outliers, model inadequacy, presence of trend, *etc.* He has also made immense contributions towards computer aided search of efficient designs for many experimental situations and for many practical ranges of parameters, shape and size of plots and blocks, diagnostics in designed field experiments; intercropping experiments; experiments with split application of inputs, *etc.*

Following new terminologies in Design of Experiments were introduced in the literature from research works of VKG and his collaborators: Generalized binary balanced block designs of type alpha; Balanced treatment incomplete block designs with unequal block sizes of Type G (for making test treatments control treatment comparisons under a heteroscedastic model when the intra block variances are proportional to integer power of block sizes); Balanced bipartite block designs with unequal block sizes; General efficiency balanced row-

column designs; Balanced bipartite row-column designs; Doubly nested partially balanced incomplete block designs; Structure resistant factorial designs; Cook and AP Statistics for detection of outliers in block designs.

7.2. Sample surveys

VKG has also made use of the combinatorics in sample surveys and because of this he has made several original contributions to the theory of survey sampling, particularly variance estimation from large scale complex survey data, unequal probability sampling, controlled selection and balanced and distance balanced sampling plans. He has also worked in the area of calibration approach of estimation of parameters. In fact, his work is pure genius with a real-world application. Nested stratified sampling; Distance balanced sampling plans; Inclusion probability proportional to size (IPPS) sampling plans excluding adjacent units, *etc.* are the new terminologies introduced by him and his collaborators. A brief of few of the above contributions is given in the sequel.

Variance Estimation based on Re-Sampling: Balanced Repeated Replication (BRR), a simple procedure for estimating variance of the estimator of a population parameter, introduced by McCarthy (1966) for a stratified design with number of units selected from each stratum as 2. It makes use of Hadamard Matrices for constructing “half-samples”. This was extended to case of p units per stratum, whenever p is a prime number by Gurney and Jewett (1975). Gupta and Nigam (1987) established link between BRR and Mixed Orthogonal Arrays (MOA) of strength two and that allowed unequal number of selections from each stratum. They have also shown that MOA of Strength two, or equivalently, equal frequency orthogonal main effect plans for asymmetrical factorials give a set of balanced subsamples useful in variance estimation. Further, Dhandapani *et al.* (1996) have shown that certain proportional frequency plans can be used with no loss in efficiency for estimating the variance of a linear statistic. Some other references in this area include Magnussen (2009), Rao and Shao (1996), Rao and Shao (1999), Saigo *et al.* (2001) and many more.

Chakraborti (1963) introduced the use of incidence matrices of balanced incomplete block designs in sample selection. To understand an association between a combinatorial arrangement (design) and sampling plan, consider number of treatments (v) as population units (N); blocks (b) as samples; block size (k) as sample size (n) and treatments in blocks as units in the sample. Totality of all the blocks is sample space (S) and probability measure $p(s) = 1/b \forall s \in S$. The selection of a block is equivalent to selection of sample and the treatments in selected block denote the units in selected sample.

Chakraborti (1963) and Avadani and Sukhatme (1973) defined an association between Balanced Incomplete Block (BIB) Design vis-à-vis simple random sampling without replacement with $v = N, k = n, b =$ total number of samples, $r =$ number of times one unit is selected, $\lambda =$ number of times two units are in the same sample. The advantage of this association is that number of blocks b is much smaller than $\binom{N}{n}$.

Gupta *et al.* (1982) proposed a family of sampling schemes with inclusion probability proportional to size (IPPS) using the combinatorial properties of BIB designs. Denote X_i as the value of the auxiliary character for unit i ($i = 1, 2, \dots, N$) of the population, and $P_i = X_i/X$ where $X = X_1 + X_2 + \dots + X_N$. The proposed plan selects a block s with

probability $p(s) = v[b(r - \lambda)]^{-1}[r \sum_{t \in s} P_t - \lambda]$; $s = 1, 2, \dots, b$ of a BIB design with parameters $v = N, b, r, k \geq n, \lambda$ with notations having their usual meaning. They proved that if $k = n$ then the selected block constitute the required sample of the desired IPPS scheme. For $k \geq n$, they suggested selecting a subsample of size n by equal probability sampling without replacement from the k units belonging to the selected block s . They proved that the resulting plan has all the desirable properties of an IPPS sample.

Recently VKG worked in collaboration with Mandal and Rajender on balanced sampling plan excluding contiguous units. To understand the context, consider the example given by Hedayat *et al.* (1988): A researcher wants to estimate overall toxicity level of the soil at a toxic dump waste site. Over an extended period of time, the site is filled with 9 mounds of waste. Researcher has enough resources to sample 3 mounds. It is believed that due to seepage, the toxicity level of adjacent mounds will be similar. Obviously, researcher would try to avoid the selection of mounds that could have similar responses. When contiguous units in a population provide similar observations, then it is intuitively logical to avoid contiguous units in a sample. Naturally, simple random sampling without replacement (SR-SWOR) is not appropriate in this case. A possible solution would be to consider a sampling plan that avoids the selection of adjacent units.

Under balanced sampling plan excluding contiguous units (BSA plans)

- (i) π_i 's are same for all units and
- (ii) π_{ij} 's are same for all non-adjacent pairs of units and 0 for all adjacent pairs of units.

Here π_i and π_{ij} are the first order and second order inclusion probabilities. These plans are useful for sampling from populations where adjacent units are correlated because of some natural ordering in time or space.

Stufken *et al.* (1999) defined support of a BSA is related to Polygonal Designs (PD). A PD is an incomplete block design (ibd) such that

- (i) each treatment has same number of replications and
- (ii) every pair of non-adjacent treatments appear in same number of blocks and every pair of adjacent treatments never appear together in a block.

Mandal *et al.* (2008, 2011) presented construction methods and algorithms to obtain BSA plans / PDs. Mandal *et al.* (2008) extended BSA plans to IPPS plans excluding adjacent units (IPPSEA plans) where $\pi_i \propto p_i$, while adjacent pairs of units do not appear in any sample and presented characterizations of these plans and methods of obtaining these plans.

One drawback of BSA plans is that unbiased estimation of Narain-Horvitz-Thompson estimator of population mean is not possible since some second order inclusion probabilities are zero. To overcome this and improve BSA plans, Mandal *et al.* (2009) introduced distance balanced sampling plans (DBSPs). Under DBSPs, (i) π_i 's are same for all units and (ii) two units with same distance have same value of π_{ij} and if the distance between units $(i, j) \geq$

distance between units (i', j') then $\pi_{ij} \geq \pi_{i'j'} \quad \forall i, i', \neq j, j' = 1, \dots, N$. Mandal *et al.* (2009, 2011) presented construction methods and linear programming approach to obtain various classes of DBSPs. Gopinath *et al.* (2018) gave two-dimensional balanced sampling plans excluding adjacent units under sharing a border and island adjacency schemes.

It may be noted that no unit-by-unit selection method is available for controlled SRSWOR / IPPS plans, BSA, DBSP. Combinatorics involving experimental designs have interesting applications in survey sampling. Optimization techniques can be useful to obtain various classes of controlled sampling plans. All this work has appeared in a textbook entitled *Combinatorics in Sample Surveys vis-à-vis Controlled Selection* by LAP Lambert Academic Publishing GmbH & Co. KG, Verlag, Germany.

Nested stratified sampling: The procedure of dividing the population into strata and then again dividing each stratum into smaller strata and drawing a random sample from each one of the smaller strata may be called as nested stratified sampling. Nested stratified sampling enjoys all the advantages of stratified sampling *viz.* better management, administrative simplicity, representation of different sub-division of population as well as obtaining estimate of population parameter for each of the sub-divisions. It helps to deal with the situations in which another factor within each stratum influences the characteristics under study. For example, in crop yield estimation surveys for crop insurance, districts of community developments blocks (CDB) may be strata and groups of homogeneous farmers within CDB are sub-strata.

Other research on survey sampling includes ratio estimators in two-phase sampling under size stratification and estimation over two successive occasions (with Pranesh Kumar in 1981) and calibration-based approach for product/regression type estimators in single/two phase with Sud and others (2014).

8. Prolific writer and collaborations

VKG has published 138 research papers in 40 International and National peer reviewed Journals (131 in Statistics Journals; 07 in Journals of Other Agricultural Sciences) that includes *Biometrika*, *Technometrics*, *Journal of Royal Statistical Society, Series B*; *Applied Statistics (JRSS C)*; *Australian Journal of Statistics*; *Journal of Statistical Planning and Inference*; *Statistics and Probability Letters*; *Sankhya*; *Metrika*; *Journal of Applied Statistics*; *Ars Combinatoria*; *Utilitas Mathematica*; *Communications in Statistics: Theory and Methods*; *Biometrical Journal*; *Journal of Statistical Theory and Practice*; *Journal of the Indian Society of Agricultural Statistics*, *Better Crops*, *Indian Journal of Agronomy*, *Agricultural Research*, *etc.*

He has written 05 text books; produced 02 electronic books; 05 Research monographs; 04 Technical Bulletins; 12 Book Chapters; 21 Project/Technical Reports; 03 Workshop Proceedings; 11 Volumes of various Journals as Guest Editor; 02 Book Reviews. He has 08 copyrights to his credit.

VKG has been a very active partner in developing statistical packages for generation of randomized layout of designs and also their analysis *viz.* *Statistical Package for Balanced Incomplete Block Designs*; *Statistical Package for Factorial Experiments*; *Statistical Package for Augmented Designs*; *Statistical Package for Repeated Measurement Designs*, *etc.* He has

also contributed significantly towards web portals “Sample Survey Resources Server” as Team Leader and “Design Resources Server” as Collaborator, which are being viewed throughout the globe.

His commitment and energy have benefitted his wide range of collaborations. He has 106 research collaborators spread across 22 organizations: 04 from US, one from Japan; 02 from CGIAR Organizations; ISI Kolkata, 05 Traditional Universities in India, 02 SAUs; 06 ICAR Institutes including IASRI. His research has received wide acceptance and appreciation throughout the globe. His research papers have been cited widely including 08 text books published by Elsevier Science, Springer Verlag, John Wiley & Sons, North Holland, Hindustan Book Agency.

The complete list of publications is given at the end before references. The references that are part of list of publications have not been given to avoid repetition.

9. Good listener and amenable to suggestions

I would like to mention here that along with his research, mentoring and managerial capabilities, VKG is good listener even to his students and juniors and filters alone the good points and adopts them

साधु ऐसा चाहिए, जैसा सूप सुभाय ।
सार-सार को गहि रहै, थोथा देई उड़ाय ॥

I would like to mention one success story. In 1998, he was Course Director for a Centre of Advanced Studies Training [now known as Centre of Advanced Faculty Training] programme. During the discussions, we the junior colleagues requested him that for spreading awareness about the advances in Statistical Techniques among agricultural researchers for adoption we should invite Agricultural scientists from other disciplines along with statisticians. He listened to us and implemented. Perhaps that was the first ad-hoc Training Programme (I stand corrected if I am wrong) in which Agricultural scientists from other disciplines along with statisticians were invited and the training was successful. Since then, in most of the training programmes, this symbiosis is being maintained resulting into adoption of advanced statistical techniques in NARES.

I have made an attempt to just present a brief. I have no words at my command to express the vast contributions made by him.

सब धरती कागज करूँ, लिखनी सब बनराय ।
सात समुद्र की मसि करूँ, गुरु गुण लिखा न जाय ॥

Besides that, outreach training programmes, interaction with agricultural researchers led to adoption of efficient designs and advanced statistical techniques. Concerted efforts made by VKG and his collaborators in disseminating advance statistical techniques to the stakeholders in NARES has led to the adoption of efficient designs like balanced incomplete block (BIB) designs, extended group divisible (EGD) designs, designs for fitting response surfaces, resolvable block designs for experimentation and sophisticated analytics of the data generated by the researchers. The linear programming approach has been used for obtaining energy requirements in agricultural sector.

10. List of published papers: 138

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2. Mahesh Kumar Panda, Tofan Kumar Biswal, and V. K. Gupta (2025). R-optimal designs for Gamma regression model with two parameters. *Statistics and Applications*, **23**, 33-53.
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16. U. C. Sud, Hukum Chandra, and V. K. Gupta (2013). Calibration approach based regression type estimator for inverse relationship between study and auxiliary variable. *Journal of Statistical Theory and Practice*, **8**, 707-721.
17. Rohan Kumar Raman, U. C. Sud, Hukum Chandra, and V. K. Gupta (2013). Calibration estimator of population total with sub-sampling of non-respondents. *Journal of the Indian Society of Agricultural Statistics*, **67**, 329-337.
18. Sukanta Dash, Rajender Parsad, and V. K. Gupta (2013). Row-column designs for $2n$ factorial 2-colour microarray experiments for estimations of main effects and two factor interactions for orthogonal parameterization. *Agricultural Research*, **2**, 172-182.
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12. Two blocks of Statistical Inference in the lecture notes on Probability and Statistics brought out by the Indira Gandhi National Open University, New Delhi, India.

16. Books' reviews written: 02

1. Written the book review of the "*Probability, Statistics, and Design of Experiments*" edited by Professor R.R. Bahadur, Wiley Eastern Limited Publication. The volume contains the proceedings of the International Symposium held in the honor of Late Professor R.C. Bose at the University of Delhi, Delhi 1988. The book review has appeared in *OPSEARCH, Journal of Operational Research Society of India*, 29, 1992.
2. Written the book review of "*Design and Analysis of Experiments*" by Angela Dean and Daniel Voss, a Springer Texts in Statistics, New York. The review has appeared in *Journal of Statistical Planning and Inference*, 87, 369-370, 2000.

17. List of technical/project reports published: 21

1. U. C. Sud, T. Ahmad, V. K. Gupta, H. Chandra, P. M. Sahoo, K. Aditya, M. Singh, and A. Biswas (2017). Methodology for estimation of crop area and crop yield under mixed and continuous cropping. FAO, Rome Publication 60, 4-87.
2. Sukanta Dash, Rajender Parsad, and V. K. Gupta (2014). Row-column designs for factorial experiments in two rows. IASRI, New Delhi. I.A.S.R.I./P.R.-11/2014.
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9. Seema Jaggi, V. K. Gupta, and Rajender Parsad (2008). Design and analysis of experiments for spatially correlated observations. IASRI, New Delhi. I.A.S.R.I./P.R.-02/2008
10. L. M. Bhar, Rajender Parsad, and V. K. Gupta (2008). Outliers in designed experiments. IASRI, New Delhi. I.A.S.R.I./P.R.-05/2008.
11. R. Srivastava, V. K. Gupta, and Rajender Parsad (2008). Study on robustness of block designs for biological assays against loss of data. IASRI, New Delhi. I.A.S.R.I./P.R.-09/2009.
12. Cini Varghese, A. R. Rao, V. K. Gupta, and Anu Sharma (2008). Statistical and algorithmic approach for improved estimation of treatment effects in repeated measurements designs. Project Report. Funded by Department of Science and Technology, New Delhi.
13. A. K. Nigam, Rajender Parsad, and V. K. Gupta (2006). Design and analysis of on-station and on-farm agricultural research experiments: A revisit. Joint Publication of IASDS, Lucknow and IASRI, New Delhi. I.A.S.R.I./P.R.-02/2006.
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15. Krishan Lal, Rajender Parsad and V. K. Gupta (2005). A study on trend free designs. IASRI, New Delhi. I.A.S.R.I./P.R.-02/2005.
16. Rajender Parsad, V. K. Gupta, P. K. Batra, R. Srivastava, Rajinder Kaur, Ajit Kaur, and Prawin Arya (2004). A diagnostic study of design and analysis of field experiments. IASRI, New Delhi. I.A.S.R.I./P.R.-01/2004.
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20. Ashish Das, V. K. Gupta, and William I. Notz (1996). A class of universally optimal block designs. Technical Report No. 572, The Ohio Stat Univ., Columbus, USA.

21. Ashish Das, V. K. Gupta and Praggya Kisan (1990). E-optimal block designs under heteroscedastic model. Technical Report No. 1190, Stat.-Math. Division, ISI, Calcutta, India.

18. List of workshop proceedings published: 3

1. L. M. Bhar, Rajender Parsad, and V. K. Gupta (2008). Outliers in Designed Experiments. Workshop Series 3, IASRI, New Delhi.
2. R. Srivastava, Rajender Parsad, and V. K. Gupta (2005). Studies on Block Designs for Biological Assays. Workshop Series 2, IASRI, New Delhi.
3. A. K. Nigam, Rajender Parsad, and V. K. Gupta (2005). Design and Analysis of On-Station and On-Farm Agricultural Research Experiments: A Revisit. Workshop Series 0, IASRI, New Delhi.

19. List of special issues of journals brought out as guest editor: 11

1. Special Issue in the Fond Memories of C. R. Rao on “Life and Work of C. R. Rao (1920-2023): The Revolutionary of Statistical Sciences” (2024). Statistics and Applications, 22, 1-693. Guest Editors: B. K. Sinha, Bimal K. Sinha, S. D. Peddada, Thomas Mathew, Bhramar Mukherjee, Nairanjana Dasgupta, Syed Ejaj Ahmed, and V. K. Gupta
2. Special Issue “Contributions to Combinatorics, Design of Experiments, Linear Algebra and Related Areas” in the memory of Late Professor Aloke Dey (2021). Statistics and Applications, 19, 1-481. Guest Editors: V. K. Gupta, Sudhir Gupta, and Rajender Parsad
3. Special Issue “Challenges and Opportunities in Statistical Data Designing and Inference in the Emerging Global Scenario” in honour of twin statisticians Bimal and Bikas Sinha on their 75th Birthday (2020). Statistics and Applications, 18, 1-350. Guest Editors: V. K. Gupta, Saumyadipta Pyne, and Rajender Parsad
4. Special Volume to Felicitate Professor Arun Kumar Nigam on his 75th Birthday (2019). Statistics and Applications, 17, 1-280. Guest Editors: V. K. Gupta and Hukum Chandra
5. Special Issue on Survey Methodology and Applications (To felicitate Professor J. N. K. Rao on his 80th birthday) (2018). Statistics and Applications, 16, 1-409. Guest Editors: V. K. Gupta, Hukum Chandra, and Gauri S. Datta
6. Special Issue on “Statistical and Computational Methodologies for Massive Datasets” (2014). Journal of the Indian Society of Agricultural Statistics, 68, 117-321 (Guest Editors V. K. Gupta, Naomi Altman, Snigdhasu Chatterjee, Kalyan Das, and Rajender Parsad).
7. Special Issue to “Felicitate Dr. Aloke Dey” (2009). Statistics and Applications, 6, 1-174 (Guest Editors V. K. Gupta, Rajender Parsad, and Ashish Das).
8. Special Issue “K. Kishen Memorial” (2008). Journal of the Indian Society of Agricultural Statistics, 62, 113-201 in honour of Late Dr. K. Kishen (Guest Editors V. K. Gupta, Rajender Parsad, and V. K. Bhatia).

9. Brought out the "Proceedings Volume of the International Conference on Statistics and Informatics in Agricultural Research", held at New Delhi in December 2006 to mark the Diamond Jubilee celebrations of the Indian Society of Agricultural Statistics. Journal of the Indian Society of Agricultural Statistics, (2007), 61, 95-279 (Guest Editors V. K. Gupta, V. K. Bhatia, Rajender Parsad, P. K. Malhotra, and H. V. L. Bathla).
10. As a Guest Editor brought out the Special Volume (Volume 3) in the honour of Dr. M. N. Das on his 80th birthday, Statistics and Application. This was released on the inaugural session of the 4th Annual Conference of the Society of Statistics, Computer and Applications, held at Rajkot during 24-26 November 2001.
11. As a member of the Editorial Committee, Brought out the Golden Jubilee Number 1996-97, Indian Society of Agricultural Statistics. This special issue of the Journal was released during the inaugural session of the Golden Jubilee Conference held at Vigyan Bhawan. The Editorial Committee for this comprised of A. Dey, V. K. Gupta, V. K. Bhatia, and A. K. Srivastava.

Besides this 09 Special Proceedings of the Conferences 19-27, SSCA (Guest Editor)

20. Copyrights obtained: 08

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6. *Statistical Analysis of Agricultural Experiments Part 1: Single Factor Experiments*. Copyright No. L-67363/2017: B. N. Mandal, L. M. Bhar, Rajender Parsad, and V. K. Gupta on July 17, 2017.
7. *Significance of Experimental Designs in Agricultural Research*. Copyright No. L-73008/2018: B. N. Mandal, Rajender Parsad, V. K. Gupta on February 02, 2018.
8. *Sample Survey Resources Server*. Copyright No. SW-9073/2017: Anshu Bhargava, Hukum Chandra, Rajender Parsad, U. C. Sud, V. K. Gupta on May 18, 2017.

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Conflict of interest

The author does not have any financial or non-financial conflict of interest to declare for the research work included in this article.

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