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Proceedings of the Symposium on "Role of Statistics in Farm Mechanisation Studies"

Chairman	:	Dr. B.S. Pathak
Convenor(s)	:	Dr. K.K. Tyagi
		Dr. M.M. Pandey

A Symposium on "Role of Statistics in Farm Mechanization Studies" was organized during the 55th Annual Conference of the Indian Society of Agricultural Statistics, on January 15, 2002 at CIAE, Bhopal. Dr. K.K. Tyagi, Convenor, introduced the Chairman and the other convenor to the delegates present. Dr. Pathak, Chairman welcomed the invited speakers. The Chairman in his opening remarks described in brief the importance of the role of statistics in various research studies relating to farm mechanization. He further emphasized the need of closer interaction between Statisticians and Agricultural Engineers. In all 10 papers were contributed for the Symposium, out of which eight were actually presented. The topics covered were as follows.

1. Statistical approach to demand forecasting for farm machinery and agro-processing equipment (Gyanendra Singh)
2. Statistical inputs required for formulating agricultural mechanization strategies (N.S.L. Srivastava)
3. Forecasting energy requirement in agricultural sector-issues and techniques (Dipankar De)
4. Statistical analysis and interpretation of field performance results for agricultural equipment (V.V. Singh, L.P. Gite, M.M. Pandey and L.S. Kot)
5. On sample selection criteria in large scale sample survey on studies relating to farm mechanization (K.K. Tyagi, S.D. Sharma, A.K. Srivastava, H.V.L. Bathla and D.L. Ahuja)
6. Statistical approach in studies related to agricultural ergonomics (L.P. Gite, P.S. Tiwari, C.R. Mehta and L.S. Kot)
7. Statistical tools and techniques used in agro-processing research (S.D. Kulkarni)
8. Use of statistics in water management (A.K. Bhattacharya and D.M. Bhandarkar)

9. Statistical approach in quality control in manufacturing of agricultural equipment (K.C. Bhardwaj)
10. Selection of optimum sizes of farm machinery and power sources-A case study of Karnal District, Haryana (R.C. Dash, N.P.S. Sirohi and K.K. Tyagi)

At the start of the presentation, M.M. Pandey, Convenor introduced each speaker. The presentation of papers was followed by discussions and questions in respect of the results presented by the participants. At various points, Chairman himself clarified various queries. Chairman also thanked various speakers and hoped that the deliberations would be of immense benefit to the agricultural scientists.

The following recommendations emerged out of the Symposium.

(i) There is a great scope for application of statistical methods and tools in research and development projects in the field of agricultural engineering. Collaborative projects may be initiated involving CIAE and IASRI in the areas of farm mechanization studies, energy forecasting in agricultural sector, ergonomic studies and development and testing of processed food products.

(ii) Research studies for estimating the requirement of various agricultural engineering inputs such as farm equipment, processing technologies and energy, from secondary data available from different sources, should be initiated.

(iii) Scientists of agricultural statistics discipline may be invited to all scientific meetings on research and development in agricultural engineering such as Workshops and Coordination Committee Meeting of AICRPs.

The papers presented and discussed are enclosed.

Statistical Inputs Required for Formulating Agricultural Mechanisation Strategies

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Agricultural Mechanisation input in agriculture is important in increasing production and productivity due to timely field operations' reducing cost of production; maximising efficiency of agricultural inputs like seed, fertilizer, chemical, water and energy; reducing drudgery in farm operations; reducing losses of produce by timely harvesting, threshing, handling and processing and improving quality of agricultural produce to fetch better prices. It is a costly input and should therefore, be used judiciously. For planning mechanisation strategies for any country or State it is necessary to have database of the status of changing scenario of land holding pattern, soil type, cropping pattern, cropping intensity, area under irrigation, farm power availability, (mobile and stationary), availability of improved implements and machinery. The steps involved in formulating mechanisation strategy for any country or State are as under :

- Present status of agriculture and agricultural mechanisation
- Identify improved implements/machinery to be introduced to increase level of mechanisation
- Fix targets for different regions according to needs
- Assess the demand of implement and machinery
- Assess what mechanisation option, manufacturing capability is available locally
- Make arrangements for procurement of those machinery either locally or from other States/Countries
- Create awareness about the advantage of those machinery to farmers
- Arrange for supply of those machinery in time and create infrastructural facilities for Front Line Demonstration (FLD) and their availability to farmers
- Arrange FLD in farmers fields
- Get feedback information from farmers
- Conduct socio-economic studies on impact of introduction of improved machinery on production, productivity, reduction in cost of cultivation and labour employment/displacement etc.
- Take mid term corrections, if needed
- Operate the programme for successful completion

At every stage of mechanisation strategy mentioned above statistical input is must for maintaining and updating databases, working out averages, finding out distribution pattern of growth of agricultural mechanisation in different States, using statistical methods for sampling of farmers and analysing data, conducting impact studies, conducting sensitivity analysis and analysing results based on statistical significance.

Forecasting Energy Requirement in Agricultural Sector - Issues and Techniques

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Energy plays a central role in national development process and in providing major vital services that improve human condition - fuel for cooking, light for living, motive power for transport and electricity for modern communication. Most of energy on the earth is received from the sun. Solar energy creates circulation of wind and ocean water, causes water evaporation and consequent precipitation. Plants use solar energy for photosynthesis and stores carbohydrates, protein, fats, oils, alcohols, celluloses and lignin. Human and animals consume plant materials as primary food to utilise its digestible energy. Plant and animal remains are converted to coal and petroleum products over millions of years, which provide the main energy sources for modern life.

In agricultural sector, energy is used in every form of inputs - human and animal power, seed, fertiliser, agro-chemical for plant protection, machinery use for various operations being operated by electricity and fossil fuels, biomass and coal for living, and is directly linked with the technological progresses. Use of the inputs by the production system results into production of crop outputs.

As a result of green revolution in India during the mid-sixties, food grains production increased from 51 Mt in 1950-51 to a remarkable level up to 208.9 Mt in 1999-00. Land productivity can be increased by adopting high yielding seed varieties, appropriate production technologies, as well as using recommended doses of fertilisers and plant protection measures. Use of improved varieties of seeds and chemical fertilisers by the farmers has increased considerably over the years. The total chemical fertiliser (nitrogen, phosphorus and potash) consumption has increased from 1.1 Mt in 1966-67 (the year of introduction of dwarf high yielding varieties) to 19.2 Mt in 1999-2000. Since 1966-67, the fertiliser consumption has steadily increased at a growth rate of 9.5 per cent. Environmental concerns resulted to partial adoption of integrated pest management particularly in cotton and rice production, and consequently pesticide consumption has decreased from 75 thousand tonnes in 1990-91 to 49.16 thousand tonnes during 1998-99.

Scientific development of the concepts and methodologies for energy management were mainly initiated after the world energy crisis in 1970s. Prior to this period, energy was relatively cheap, and thus any imbalance between demand and supply was invariably met with augmentation of supply. The emphasis was more on engineering and technological improvements. Energy planning was mainly focussed on energy sub-sectors as electricity, oil, coal, etc.

with minimum co-ordination among them. Subsequent to the energy crisis, greater co-ordination between energy supply and demand options were initiated for more efficient demand management and conservation. The energy-macroeconomic links were examined more systematically. The concern on environment has recently crept in leading to more close look at the energy-environmental interactions.

Energy management, therefore, attempts to

- Analysing energy consumption pattern and economic appraisal
- Developing strategies for energy conservation and adopt appropriate technologies which are more energy-efficient
- Determining appropriate energy resource-mix; all for minimising energy cost
- Energy education, information and developmental schemes etc.

Energy management is essentially a continuing process - regular review of energy consumption pattern through assessment of present pattern of use as compared to previous situations is required to capture the dynamic character of energy demand.

Anticipating major upward shift in the energy demand in the agricultural sector, the ICAR has operated an AICRP on "Energy Requirement in Agricultural Sector" since 1971. The project since its inception has endeavored to conduct research on energy in the context of its increased demand resulting from modern technological inputs to agriculture and necessitated due to the increased demand for food, feeds and fiber on account of population pressure and rising standards of living.

Among the various production systems in agriculture, thrust has been laid on crop production systems operating over time in different agro-climatic regions of the country. Through systematic studies, energy audits have been conducted to capture the uses of different energy resources in crop production and the energy outputs (in terms of crop yields) obtained from the production processes by individual farmers in selected villages on whole village approach.

Statistical Analysis and Interpretation of Field Performance Results of Agricultural Equipments

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In testing of agricultural equipment, the main interest is to compare them in relation to their output, quality of work and requirements of energy in their use. Normally replicated trials are carried out and average values are reported which many a times lead to convey wrong informations. For this statistically planned experiments could be better solution. An equipment may be better in terms of output, economy or comfort of operation than other equipment. It is always emphasized that an experiment should be planned in advance to get proper results. The three basic principals of field experimentation to be followed include replication, randomization and local control. The plot sizes generally used in agriculture may vary from 50 m^2 to 200 m^2. However, for carrying out performance trials with farm tools and equipment, large plot sizes are often required. i.e. about 200 to 2000 m^2 depending upon the tools/machine to be evaluated.

It is a normal procedure to plan the complete experiment in advance and work out a lay out of experimentation. The two designs most commonly adopted in evaluation of agricultural equipment are

1. Randomized block design
2. Split plot design

After collecting the data on the desired parameters, tabulation of results is done as per the requirement of design, analysis of variance is carried out and the critical differences at 1% level and 5% level of significance are calculated to compare the different treatments.

On Sample Selection Criteria in Large-Scale Sample Survey on Studies Relating to Farm Mechanisation

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Modernisation of Agriculture is a felt need of the day. Equally important are, reduction in cost of production, maximisation of returns, reduction in the drudgery associated with various agricultural operations; and improvement in the productivity of land and labour. The mechanisation has been well received world over as one of the important elements of modernisation of agriculture. In India, though there has been a considerable progress of mechanisation in agriculture, its spread has been in the most uneven manner. Hitherto, governmental efforts have mostly been confined to the promotion of manual and animal-drawn tools and implements. Power-drawn equipments have also gained momentum due to the concerted efforts of the government, credit institutions and the industry. No sincere efforts have, however, been made for the identification of location-specific farm implements and machines and their promotion in the respective areas.

Modernisation of agriculture should not only be guided by the goal of higher returns to the farmers and to the industry, but also by its contribution to the balanced agricultural development of different regions/areas having diverse socio-economic and agro-climatic conditions. Thus, considering the expanding needs of the agricultural mechanisation in the country, it has become necessary to ensure that the needs of the farmers are duly met in terms of local needs, quantity, quality and social benefits. This can hardly be accomplished without taking definite policy measures and the strategic planning. It is in this context that the Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India has given IASRI a project to study various factors which have bearing on agricultural production/productivity in different states/agro-climatic zones, and formulate appropriate farm mechanization strategies for them.

The programme envisages the conduct of an in-depth study, at micro-level, of the socio-economic, agro-climatic, agronomic, infrastructural and other relevant factors prevailing in different agro-climatic zones of the country, which have a bearing on the spread of agricultural mechanisation, agricultural productivity therein; and formulation of appropriate long-term farm mechanisation strategies for the respective zones. It is likely that for a number of zones/states, a single set of strategy/programme may not be uniformly conducive to the spread of farm mechanisation and all-round and sustainable agricultural development there. As such, appropriate packages of agricultural mechanisation strategies and programmes for different zones/states need to be formulated according to the present status, potential and future needs of agricultural mechanisation there.

The study is being conducted for each Agro-climatic Zone/State covering 120 districts, representing a mix of developed, developing and least developed pockets. The sampling design adopted is stratified multi-stage random sampling. The strata being the States/group of States. India is divided into 29 States and 6 Union Territories comprising 585 districts. Some of the States like Punjab, Haryana and Western part of Uttar Pradesh etc. are highly mechanised while in States located in hilly areas especially Northern Eastern Hills etc., mechanisation levels are of low order, in rest of the States/UTs, the mechanisation levels are of moderate levels. Out of total number of districts, at primary stage sampling unit level, a sample of 120 districts has been selected randomly with due consideration to mechanisation levels following proportional allocation. After allocating the total sample size to different strata, the districts within each stratum have been arranged in ascending order of magnitude of mechanisation indices (total number of tractors per thousand hectare unit of gross cropped area in each district), which varies in between 0 and 75. Within each stratum, homogenous groups of 10 or more districts have been prepared and from each group, at least 2 districts (1 out of about 5 districts) were selected randomly. The sample of districts so selected has been post-stratified according to agro-climatic zones to ensure zone-wise representation. From each selected district, at the secondary stage, a random sample of 40 villages has been selected. Accordingly, the total number of selected villages is 4,800. The sample size has been determined on the criterion of desired level of efficiency (95%) at a tolerable margin of error (5%) for characters having 40 to 50% coefficient of variation. In this case, the estimates will be developed at the Agro-climatic Zone/State-level. Keeping in view the level and adoption of mechanisation, out of each selected village, at the tertiary stage, a sample of 10 households has been selected. Hence, the total number of randomly selected households is 48,000.

Statistical Approach in Studies Related to Agricultural Ergonomics

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Agricultural ergonomics is such a discipline where the experimentation involves agricultural science as well as biological science and therefore, statistics has a big role to play in getting useful results out of the experiments conducted to generate knowledge and data in this discipline.

The purpose of conducting an ergonomical experiment is not just to limit the knowledge to a single experiment but drawing inferences for general application is the goal.

In agricultural ergonomics, the statistics is used in the following areas:

(i) Collection, compilation and interpretation of anthropometric and strength data of Indian agricultural workers.

(ii) Survey of accidents in Indian agriculture and interpretation of the accident data.

(iii) Assessment of impact of follow up programme conducted for minimization of agricultural accidents.
(iv) Assessment of ergonomical problems faced by agricultural workers.
(v) Calibration of subjects for heart rate-oxygen consumption relationship.
(vi) Comparison of various tools and equipment in terms of human comfort, energy expenditure and body discomforts.
(vii) Comparison of different personal protective equipment for assessing their efficacy in reducing the severity or exposure to stress agents.
(viii) Assessment of health hazards due to various stress agents like noise, vibration, dust etc.

The outcome of an experiment can be predicted well in exact sciences like physics and chemistry. However, in agricultural sciences it is difficult to predict results. Even if the experiments are repeated under exactly identical situations, the observed results will differ from one another. Also when it is an experiment involving agricultural and biological sciences, the situation becomes more complex and the interpretation of results is difficult.

Statistical Tools and Techniques used in Agro Processing Research

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Agro Processing related research activity mainly involves process, product and equipment development. These are evaluated/assessed on account of raw material use pattern, energy use efficiency, recovery of end-product, cost effectiveness, product quality and safety and environmental aspects. Different statistical techniques are used for broad analysis, and demarcations are fixed based on desired/undesired parameters or significance or otherwise of the null hypothesis. Ordinarily, statistical analysis is done using chi square test, paired 't' test 'F-test'- analysis of variance (one way and two way), Central Composite Rotatable Design (CCRD), standard deviation, coefficient of variation, etc. in different type of work. It has been observed that in case of proper design of experiments, the statistical analysis provides enough accuracy and guideline in interpretation of the results for arriving at a decision on rejection or acceptance of the process, technology, equipment or product. However, in case of high value end products the statistically non-significant difference leads to the loss of considerable/appreciable monetary value. The processor would not afford to do away with it in actual material sense. Under such circumstances, it becomes necessary to fix-up the arbitrary tolerance limits matching to ones own capacity to accept/bear the loss. Such situations demand for newer statistical tools/approaches. Aspects related to various methods adopted in agro processing research and their limitations have been highlighted in the paper.

Use of Statistics in Water Management

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Statistics is a versatile tool for analysis and interpretation of data. Water, as a natural resource, is of concern to everyone. Except rain water, the two other available forms of this resource such as surface and ground water, are degradable in quality. There is a competing demand for water by various sectors. Fresh water availability per unit of land for agriculture is apprehended to decline in the coming years. This makes water management an important issue. Water management refers to all the activities that ensure getting maximum benefit per unit of water without degrading its quality and also the quality of land over which it is to be used. Water and land management are, therefore, conceptually inseparable.

The planning stage of water management for agriculture involves assessment of the water resources, assessment of the water demands and allocation of the available resource to meet the demand optimally, after accounting for the unavoidable losses. Execution of the plan and monitoring its impact are the subsequent administrative and technical follow up action. Collection of historical data, field experiment data, their analysis and interpretation are relevant to both planning and execution stages of water management. It is easy to comprehend that in view of the diversity of the country with respect to rainfall and other climatic parameters, soil, land, surface and ground water, crops, energy availability, farmers and their socio-economic condition, the data base is also diverse and large. Use of statistics helps handling such large and diverse data base efficiently for developing comprehensive plans. Data collected during the execution and monitoring stages, which are location specific and in more details than was perhaps available at the planning stage, when analysed, help in modifying the plan from time to time and take suitable corrective measures to mitigate problems that were not apprehended at the planning stage.

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The elementary statistics, mean, is invariably used to describe the nature of rainfall, groundwater table, soil and water salinity, land slope, soil texture and several such variables which may vary with time, space or both. Simple mean may not sufficiently describe certain variable for which geometric mean is used. Coefficient of variation is used to understand the range of variability. A large spatial variability makes the planning process complicated and may require homogeneity test to segregate different parcels of lands for developing a comprehensive plan where the executive components are different for different segments of the planned area. Rainfall, the primary resource of all waters, is a stochastic hydrologic event, occurrence and magnitude of which are governed by the laws of chance. It may sound strange that chance also has laws (vis-a-vis the laws of motion), but the entire subject of probability deals with such laws. Rain water availability is invariably assessed using the laws of chance and the associated statistics. The use of 75 or 80 per cent dependable rainfall is common in planning for water resources. Which hydrologic data fit which probability distribution has been and still is a major topic of investigation. The goodness of fit is ascertained using chi-square test.

Much the same way as rainfall, stream flow is also a chance constrained variable. Knowledge of stream flow availability at different times in a year is crucial to plan for water diversion or water storage systems for an irrigation command area. Stream flow records for large rivers are maintained and can be used directly for assessment of water availability for storage or diversion on a probabilistic basis. There are, however many streams draining smaller catchments for which records are not maintained. In such cases, empirical relations developed between rainfall and stream flow for similar watersheds where recorded data are available, are taken. Statistical procedures are used to develop such empirical relations through regression analysis. Both two variable and multi-variable, linear or non-linear regression relations can be developed relating the dependent and the causative independent variable(s) using statistical procedures. Rainfall-runoff relations, runoff-soil erosion relations (either simple or thorough morphologic parameters) are used in runoff estimation and calculate the required dead storage of the reservoirs, respectively. Calculation of Silt Yield Index (SYI), developed by the All India Land Use and Soil Survey Organisation is a relevant example of the latter and the SYI parameter is routinely adopted for categorizing priority watersheds for treatment.

Crop water demand, the losses of water during its travel from the source to the field as well as in the field, interaction of water with fertilizers and water production functions are established through field experiments conducted following an appropriate statistical design. Experimental design and analysis of the experiment results using standard statistical procedures help in accepting or rejecting a hypothesis with a given level of confidence. Based on these experimental findings, a planner is well equipped to develop alternative plans and foresee the consequence of each at the planning stage itself. If the crop water demand is estimated using empirical formulae, statistics is used in first analysing the causative meteorological parameters which again, are probabilistic in feature. The alternative plans are further examined for their economic viability.

During an experiment, it is possible to include a relatively larger number of causative factors as "treatments". For example, irrigation demand of crop is a function of the crop, the climatic parameters, the water quality, the soil chemical composition and the depth to groundwater table. Under controlled condition of an experiment, it is possible to investigate the effect of different levels of the independent variables on the crop water demand and the performance of the crop. In the field, many of these are not controllable though they can be recorded as they are. Analysis of co-variance using the data of a controlled experiment helps in understanding the likely crop behaviour where the water may be given in a controlled fashion and in known quantities but most of the others cannot be controlled.

Curve fitting, a well developed statistical procedure, is extensively used by researchers to relate the dependent and the independent variables. These relations are useful in predicting the parameter under consideration for a known value(s) of the causative variable. An example is the infiltration versus time relation, developed using the cylinder infiltrometer test data. Such relations help in estimating loss from water storage structures with passage of time (hence, the temporal availability of water to meet irrigation demand), in designing furrow, border, check basin, sprinkler and drip irrigation systems and in estimating runoff from a watershed. Curve fitting procedure is used in several other applications related to water management.

Soil texture, determined through granulometric analysis of a soil sample, is a deterministic property of the soil. Soils taken from different places in a field will show different granulometric properties due to spatial variability. To categorise the soils of a large watershed into different textural groups, statistics is used for averaging or segregating soils based on their granulometric properties. Soil texture is an important parameter governing water holding properties and is used for deciding appropriate irrigation depth and frequency which are water management activities.

The land use map, the land capability classification, the hydrologic grouping of soils, climatic categorization of regions as arid, semi-arid, sub-humid, humid, estimation of drainage need, calculation of leaching requirement, all of which have influence in planning and execution of water management, are done by statistically analysing a vast data base.

Water demand in the future needs to be assessed properly to decide on the scale of construction of water storage and diversion system that are to last for many years after construction. The water demand is a random variable. Future demand should not be computed deterministically by unique curves as functions of time. In matching demand and supply, it is important to consider the stochastic nature of both. Stochastic modelling for water management planning is done to understand the cause-effect relation between important variables which strengthens the plan. It is quite common to find that the actual consumption of water after creating a water resource facility does not match with what was anticipated. Similarly, the anticipated increased crop productivity after ensuring water availability for irrigation is not realised. These issues are examined during monitoring stage on the basis of sampling. Sampling procedures, probable sampling parameters, analysis of the data collected during sampling and interpretation of the analysis result are governed by statistical principles.

The realm of non-parametric statistics was originally developed for behavioral studies where generally, qualitative information are to be analysed. However, there has been considerable use of this sub-branch of statistics in the area of water management study. It is particularly useful in checking the performance of hydrologic models by comparing the model output with observed data. Since, the observed data are usually short, fitting probability distribution (using parametric statistics) may become questionable.

Statistics is an analysis tool. The responsibility of decision making based on the statistically analysed results lies with the analysts. The decision will be relevant if the data were correct. The importance of correctness of the recorded data cannot be over emphasised. The result of the statistical analysis can lead to erroneous decision if the data were incorrect. Compared to many other countries, India is relatively at a disadvantageous position as her statistical data base of the land and water resources is not strong. Except perhaps Indian Meterological Department, which has a strong infrastructure for recording and maintaining rainfall and other climatological data all over the country and the Groundwater Boards which maintain pre-monsoon and post-monsoon groundwater table data, no other organisation exists for centrally sponsored data collection and analysis pertaining to small stream flow, water table fluctuation in the crop root zone, physical and chemical health of the soil, surface water logging and impact of these on the crop performance. Statistics can be more meaningfully used if such a data base is built with correct data and the data base is updated from time to time.

Statistical Approach in Quality Control in Manufacturing of Agricultural Equipment

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What is Quality?

J.M. Juran has defined quality as "Fitness for use"

Phillip B. Crosby has defined it "Conformance to requirement"

W. Edwards Deeming defined it "A predictable degree of uniformity and dependability at low cost and suited to market"

Thus the definition of quality can be generalized as "A human value that seeks satisfaction by having a product, person, service, process, environment, activity, event or emotion, meet or exceed a desired or anticipated expectation"

Why Quality?

Consumer is demanding quality

Others in world market place have taken lead in quality

Improvement in quality is a matter of economic survival

Quality improvement can reduce cost and improve productivity and profitability

Quality yields greater customer satisfaction

Basic Principles Underlying Statistical Quality Control Techniques

No two things are exactly alike

Variation in a product or process can be measured

Things are according to a definite pattern

Whenever things of the same kind are measured, a large group of the measurements will tend to cluster around the middle

It is possible to determine the shape of the distribution curve for parts produced by any process

Variation due to assignable causes tend to distort the normal distribution curve

Tools of Quality

Statistical methods of quality control give a way to picture and control quality through the use of these 'Tools of Quality'

1. The histogram or frequency distribution
2. The control chart

The Histogram or Frequency Distribution

In many families it is a custom to have a picture taken each year. Just as a family picture is a snap short of a group of people, the histogram is a snap short of group of parts from a manufacturing operation. It shows how a process is operating at a given time. A histogram is simple to construct. It is nothing more than a frequency distribution put into block form.

Three questions can be answered by a quick look at the pattern of the histogram.

1. Is the process production parts to the bell-shaped curve?

Because the histogram is roughly bell shaped, then for practical applications we may say

(a) The process appears 'normal' and stable.

(b) Variations are generally due to chance causes.

However, when the histogram is not roughly bell shaped

(a) The process is not 'normal'.

(b) Assignable causes are influencing the variations. In special cases a frequency distribution or histogram of measurements from a stable process will not match the normal curve, but in most manufacturing operations measurements from a stable process will make a good match to the normal curve.

2. Where is the process centered?

The average of the histogram and the specification midpoint are close together; therefore, the process is well centered.

When the average of the histogram and the specification midpoint are far apart, then the process setting needs some adjustment.

3. Is the process capable of meeting the engineering specification?

The spread of the process falls withing the specification limits; therefore the process is estimated to be capable of meeting the engineering specification.

It may be remember that the histogram is merely a snap short of the process. If we take another set of data at any other time, the picture may be different. However, the information we have on the process tells us that it is capable of meeting the engineering specifications.

The frequency distribution and the histogram are used for

- Evaluation or checking processes
- Indicating the need to take corrective action
- Measuring the effects of corrective actions
- Comparing machine performances
- Comparing materials
- Comparing vendors

The Control Charts

If the frequency distribution is like a snap short of a process, then a control chart is like a movie - a continuous series of smaller pictures. A control chart is a record of the results of periodic small inspections. The control chart is a running record of the job. It tells us when the process is running smoothly and when needs the attention. It is a very good tool to know a problem and correct the problem successfully.

There are two types of control charts.

1. Variable Chart

   This type of chart is used where a dimension characteristic is measured and the result is a number.

2. Attribute Chart

   This type of chart is used where a dimension or characteristic is not measured in number, but is considered either good or bad.

   The variable chart may be average and range chart, median and range chart and individual and range chart.

Selection of Optimum Sizes of Farm Machinery and Power Sources - A Case Study of Karnal District, Haryana

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Power and machinery is the single largest cost component constituting about 60% of the total investment cost on mechanized farm. Thus, the profit of a farm depends, to a great extent, on the appropriate mechanization planning of the farm. The size of power source and machinery system is, in general, directly proportional to their cost. Selection of proper size of power source(s) and its matching equipment is extremely important for an efficient mechanization planning.

The main constraint in the planning of farm mechanization has been due to the complexity of available machinery systems and their diversity with respect to type, size, number and operational characteristics. The process is further complicated in multiple cropping because the optimal selection of power and machinery must also satisfy the operational requirements of all the crops simultaneously with constraints of maximum machine efficiency and minimum capital investment. Several models have been developed for the selection of agricultural machinery system using different techniques, like linear programming, heuristic models, dynamic programming, and least cost approach.

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All those models were crop and location specific. In India, a few studies have been conducted for the selection of power and machinery combination for the given farming situation. No information on the selection of machinery for paddy-wheat crop rotation is available, which is an important cropping system occupying about of 10.5 m ha of area in the country.

In the present study, computer based mathematical models were developed using least cost technique for the selection of power and machinery system for paddy-wheat crop rotation. The program, written in C language, was used to select combination of power sources and farm equipment suitable for different farm sizes.

The input data used in the model were collected from both primary and secondary sources. Primary data were obtained from field experiment and survey of the market and farmers of the study area. To validate the output of the model, Karnal district of Haryana state was selected as study area, where paddy and wheat were the two major crops occupying an area of 81.2% of the total cropped area of the district.

Stratified two stage random sampling technique was used to select sample farmers from 6 blocks of the district. Two villages from each block and 9 tractor-owning farmers from each village were selected randomly. A total of 108 farmers were contacted for collection of data in the year 1999-2000 by personal interview method. Information was collected from each farmer on the existing inventory of farm power and machinery, use pattern of machinery and power, cultural practices followed, and yield of paddy and wheat crop. The information was analyzed for different categories of farmers and a database was developed for the given cropping situation. Model output was verified in two stages. The first stage included testing the sensitivity of the model to changes in major parameters to verify that the changes produced in the selected tractor-machinery set were reasonable. In the second stage, model validation was done using the database developed for the area.

Based on the results of the study, following conclusions could be drawn:

1. Marginal farmers in the study area did not own tractor but hired them. Tractors up to 26.12 KW (35 hp) were very popular among farmers and were possessed by 71% of the farmers of the sample, whereas tractors above 26.12 KW were owned by only 38% of the farmers. Small and semi-medium farmers had tractors below 26.12 KW (35 hp).

2. Tube wells were the main source of irrigation and electric motor operated pump sets were extensively used to lift ground water. Electric motors up to 3.73 KW (5 hp) were more prevalent, whereas diesel engines above 5.6 KW (7.5 hp) were more popular.

3. Unit gross power availability was observed to be 12.29, 7.14, 5.40, and 3.34 KW/ha for small, semi-medium and large category of farmers respectively. Average power available among all categories of farms was higher than the national average of 1.15 KW/ha.

4. Disc harrow was the most popular implement among farmers and owned by 96% of the farmers in the sample followed by cultivator (87.96%), tractor trailer (61.11%), multi crop thresher (57.4%), puddler (46.3%) and leveler (45.37%), in that order. Seed-cum-fertilizer drill was the least used equipment and owned by only 7.4% of the farmers. Number of equipment available per tractor was found to be highest on large farms and lowest on small farms.

5. Tractor power requirement was found to increase with farm size. The regression equation between optimum power of tractor and farm size was predicted to be of the following form: $Y = 7.2955 + 1.9556 X$, where Y = Optimum PTO power of tractor, KW and X = farm size, ha.

6. The power requirement per unit area followed an inverse relationship with the farm size, which initially decreased as the farm size increased but then stabilized at a value of about 2.3 KW per hectare.

7. Cost of irrigation by electric motor operated pump with flat rate mode of payment of electricity energy, was highest up to 2 ha farm. Beyond 2 ha, cost of irrigation by diesel engine was higher than cost of irrigation by electric motor with both the options of paying electricity charge. Tractor and electric motor combination was economical than tractor and diesel engine combination.

8. The size of equipment was found to increase with the farm area. The minimum sizes of available equipment were adequate to meet the requirement up to 4 ha farm.