FORECASTING MODELS FOR CROP YIELD IN CASHEW *(ANACARDIUM OCCIDENTALE L.)*

By

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THESIS

submitted in partial fulfilment of
the requirement for the degree

Master of Science (Agricultural Statistics)

Faculty of Agriculture
Kerala Agricultural University

Department of Statistics
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
Mannuthy - Trichur

1987

Declaration

I hereby declare that this thesis entitled "FORECASTING OF MODELS FOR CROP YIELD IN CASHEW (*Anacardium occidentale*. L)" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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To my beloved Mother
and in loving memory of
my Father.

ACKNOWLEDGMENT

I express my heartful gratitude and indebtedness to Dr. K. C. George, Professor and Head, Agricultural Statistics, Kerala Agricultural University and the chairman of the Advisory Committee, for his constant encouragement, valuable guidance, patience and inspiring supervision not only during the research and preparation of my thesis but through out my entire M.Sc. programme.

I extend my sincere gratitude to Sri. K. L. Sunny, Assistant Professor of Agricultural Statistics; Dr. S. Balakrishnan, Associate Director of Research; Dr. C. T. Abraham, Assistant Professor of Agronomy; for their guidance, assistance and critical supervision rendered through out my research work.

I am highly indebted to Smt. K. P. Santhabai, Junior Programmer and Kum. Geetha. U., Junior Assistant Professor of Agricultural Statistics, for their help in the analysis work of my thesis and also for their timely support and encouragement which inspired me to carry out my work successfully.

I express my sincere thanks to the staff and students of the Department of Statistics, College of Veterinary and Animal Sciences, for their co-operation and encouragement which helped in creating a pleasent working atmosphere.

I would like to thank the Directors and staff of M/s.COMPUSOFT Software Consultants, Bangalore, for their tremendous effort and dedication they have shown for the timely completion of the editting and printing of this thesis.

I am grateful to Dr. K. Radhakrishnan, Dean-in-charge, College of Veterinary and Animal Sciences, Mannuthy, for the facilities provided for the research. The award of the fellowship by KAU is duely acknowledged.

I am highly indebted to my mother and sisters for the unfailing support, encouragement and patience they have shown during the course of my two and half years of study. I take this opportunity to thank a very dear friend, Sri. T. Jathinder for all the help and encouragement he has rendered during my period of study.

Finally, I express my heartfelt gratitude and indebtedness to my husband Sri. N. Govind for his constant encouragement, interest, patience and support in brightening and broadening my horizons of professional knowledge and skill.

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INTRODUCTION

"Progress is not merely improving the past,
It is moving forward towards the future"

-Khalil Gibran

Progress is today the keyword to human existence. 'To prosper' has become the basic intention of every aspect of human life. Continents, the world over forge ahead with latest inventions and technology, only to progress from what they were to a new level of supremacy - in some cases to reign over others while in other cases to improve their old standing.

Progress does not just happen. The ability of man to look through his past happenings, understanding it and looking ahead along those lines are the foundation for his progress. One might say `progress' and `foresight' go hand in hand.

On a larger perspective, a nation progresses only when her enlightened inhabitants study her past and forsees her future, incorporating the necessary changes well ahead, so that she has nowhere to go, but forward. Thus foresight helps man to forecast his future thereby assessing what he has at hand and how he should make use of it resourcefully.

1.1 Forecasting in Agriculture

Foresight in the field of agriculture is of vital importance, as a nation thrives on its flora and fauna. Over the past decades, forecasting the yield of agricultural crops using crop weather model, has slowly but steadily gained top priority mainly due to the fact that

1. It helps in formulating an estimate of the expected production of the crop well ahead of the harvest. Such estimators are very useful for advanced planning for food and other relief measures in areas with impending crop failures.

2. Monopolising on the crop weather relationship, it evaluates how much the increase in production of different crops in a given year is attributed to fluctuation in weather alone and how much to changes in technological factors.

But these changes in outlook did not come about off hand. Centuries of scientific research on crop weather models by scientists working in a variety of disciplines like agrometeorology, plant physiology, plant breeding agricultural economics and agricultural statistics led to numerous research projects and publications on aspects of crop weather relationship. The realisation of the effects of meteorological factors on crop production and hence their impact on world food supply, paved way for a renewed interest in a continous world wide watch of crop prospects and forecast.

Various mathematical and statistical models and techniques on crop weather relationship were developed and utilised . However, practical exploitation of the knowledge and information on crop weather relationship for the assessment of crop yield from weather data, had not yet satisfactorily advanced and progressed to the extent expected.

One reason for the slow development in assessing the crop yield based on crop weather relationships has been the apparent lack of interest by policy making and production planning bodies for real time crop assessment. This might be due to crop production policies which existed in 1950's and 1960's in major food exporting countries and to the large surpluses at that time in these countries as well as in the world market. Under these conditions of food glut, there seemed to be no need for monitoring the effect of weather and climatic factors on crop yields from meteorological data on a real time basis, since survey reports on crop and stocks provided adequate and plausible information.

Annual fluctuations in crop production are accepted feature of regional or world food supply, but usually these fluctuations tend to off set one another on a regional or global scale. But because of the adverse weather conditions occuring in 1972 simultaneously over the major producing areas of the world, it was then realised that a repetition of this adverse weather pattern over successive years would have disasterous effect on both, developing and developed countries.

In addition to the effect of these annual weather fluctuations, there was also evidence that, during the past one or two decades, the seasonal weather pattern did not show the disasterous variability or extremes that can be expected from long term climatic records for the region of the Indian sub continent. Eventhough the "good" weather trend resulted in a series of years with high crop yields in India, it cannot be expected that the crop yields of next several years will stay at these high levels. In this regard, the crop weather models can be utilised as useful and important research tools for the interpretation of climatic fluctuation in terms of their impact on crop production over large areas of the nation.

Countries such as USA, USSR, Canada, Israel, Brazil, Iran, Australia, Italy, Japan and Argentina are already using such crop weather models and weather based estimates for various agricultural crops on an experimental and operational basis. International organisations such as World Meteorological Organisation (WMO) and Food and Agriculture Organisation (FAO) have also substantially increased their effort to provide real time information on weather and climate fluctuations and their impact on regional and global surpluses and shortfalls in food productions. The need for more research into crop weather models, development of operational crop yield assessment models and their importance in national agricultural plannings have been more and more widely recognised in many countries of the world.

1.2 Development of crop weather models and its classification.

A knowledge of weather factors that have direct effect on yield will help the farmer in taking appropiate decision in relation to weather for the choice of crop, sowing, transplanting, scheduling of irrigation, fertiliser application and other management practises. Thus agriculture in a country cannot be a complete success unless it takes into account the vagaries on the crop.

In physical sciences, the term "model" is used "to provide an explanation for certain phenomena and to postulate underlying processes which give rise to the observation under inspection" (Yarranton, 1971). Regardless of approach, a crop weather models may be defined as a simplified representation of a complex relationship between weather or climate on one hand and crop performance on the other by using mathematical or statistical techniques.

According to Mead (1971) the use of high degree polynomials to represent biological situations should properly be defined as a mathematical representation rather than a model. Because of the common use of the term model, it is essential to identify the various models on the basis of the approaches used in crop weather models.

1.2.1 Approaches

Mc Quigg (1976) described two basic approaches to model the impact of meteorological variability on crop yields.

1. the physiological or causal approach which is based on detailed knowledge which takes place within a given time interval in the plant or soil systems and in the immediate atmosphere environment of the plant.

2. the statistical or correlation approach which is based on the application of some sort of statistical technique to a sample yield statistics from an area and a sample of weather or climatic data from the same area.

Newman (1974) distinguished between two approaches.

1. modelling based on mathematically formulated relationship with empherical constants, when necessary.

2. modelling involiving some type of statistical regression technique for fitting statistically the best possible empirical relationship between climatological variables and crop production statistics.

Stewart (1975) formed two broad categories based on the degree of empiricism used, i.e.

1. regression analysis in which the coefficients are solved by least square technique and which uses a minimum of physical interpretation.

2. simulation models which emphasize the mechanisms of the processes being studied through a series of equations that are solved simultaneously.

Haun (1974) proposed a wheat yield prediction system that is based on "cause and effect" relantionship.

Finally, Baier (1976) classified crop weather models into three categories.

1. crop - growth simulation models.
2. crop - weather analysis models
3. empherical statistical models.

In crop growth simulation models, defined as a simplified mathematical representation of the complex physical, chemical and physiological mechanism underlying plant growth response, the impact of meteorological variables (radiation, temperature, wind, humidity etc.) on specific processes like photosynthesis, transpiration or respiration can be adequately simulated by means of a set of mathematical equations which are based on experiments or available knowledge of the particular process.

Crop weather models are models which provide a running account of the accumulated crop responses to selected agromoteorological variables as a function of time. These models often use soil moisture or evapotranspiration and other derived or observed data on a day to day basis and relate these data together with other information to morphological vegetative growth or crop yields. Standard climatic data are used as primary inputs; some processes or crop response function like soil moisture distribition or fertiliser response are preprogrammed but conventional statistical techniques are used to evaluate the weighing coefficient in the final model. Crop weather models proposed by Haun (1974) fall into this category.

Empherical statistical models are models in which one or several variables representing weather or climate, soil characteristics or a time trend are statistically related mostly to seasonal yield or other crop statistics. Here sample of yield data from an area and a sample of weather data from the same area are used to produce estimates of coefficients by some sort of regression technique. The validity and potential application of such models depends on the representatives of the input data, the selection of variables and design of the model.

The approach does not easily lead to an explanation of the cause and effect relationship, but is a feasible procedure in making use of available yield and climatic data for weather based evaluations of historical, current and to some extent expected crop yield statistics.

1.3 The Cashew Tree

Cashew, Anacardium occidentale L. belongs to the large flowering plant "Rutacles" having twelve families with 324 genera and 4000 species. Cashew, a native of Brazil was brought to India by the early Portugese settlers during the 15th Century and was used mainly to harness the problems of soil erosion. This particular plant is found in the temperate zone within 27^{o} N to 28^{o} S of the equator. It is not stereo typed with any particular soil type and can be grown in any type of soil provided, they are not highly acidic. The rainfall requirement of this tree also does not follow any hard and fast rules. Cashew cultivation can be carried out equally effectively in regions having only 30 cms. of rainfall to regions having 400 cms. of rainfall. The temperature fluctuations this sturdy tree can withstand, range from a minimum temperature of 17 ^{o}C to a maximum of 34-35 ^{o}C. While the tree flourishes under maximum sunlight it deteriorates in regions experiencing mist and snow.

Cashew is a plant nutured solely because of its commercial value. The cashew kernel, cashewnut, cashew apple, the cashewnut shell liquid are all products of the cashew tree which rank high in the national and international trade markets for their nutritive and commercial value.

Unfortunately cashew as a crop has not been taken seriously by the farmers although the demand for cashew kernels has been growing steadily in the world. This is partly because cashew was treated as a wild crop and has become economically valuable only in recent decades. It is found mainly on lands unsuitable for the cultivation of other remunerative crops. One implication of it being grown on relatively poor soil and terrain scattered all over is that it is difficult to give cashew the kind of close attention that crops generally recieve. Since it grows on inferior soil generally unsuitable to most other crops and is sturdy enough to withstand long spells of drought the price that cashew fetches now makes its cultivation a potentially important source of income from the available inferior lands where it can be grown.

Considering the pattern and trend of India's report of cashew kernel in future, certain developments which have taken place in recent years needs careful review. At the outset it must be pointed out that the Indian Cashew Industry grew to enormous heights in the last few decades, largely due to a steady supply of raw cashew nuts recieved from East African countries. In recent years most of these countries have set up their own processing units with a view to consuming their production of raw nut locally thereby leaving less and less quantities for the Indian industry. There have also been certain factors which have affected the production and collection of crop in these countries as a consequence of which availability of raw nut from these countries for the Indian Cashew Industry has been drastically curtailed. Thus the Indian Industry can no longer depend on the massive imports of raw cashew nut from other countries.

Until recently growing of cashew was not an economic proposition as the remuneration received by the growers was very poor. This was one of the major reasons why the world production of cashew nuts suffered a set back. The wide gap between production of raw cashew nuts and the demand for the finished goods inevitably lead to a sharp rise in prices of raw cashew nut in the producing countries as well as for cashew kernels in the International market. The imperative necessity today is to meet the growing demand and this would necessitate in generating reasonable returns to growers.

1.4 Objectives of the present investigation

In the present investigation the development of statistical crop weather models for the pre-harvest forecast of cashew crop is conducted with the following objectives

1. to develop suitable and reliable statistical methodology for the pre harvest forcast of crop yields by constructing different empherical statistical crop weather models adopting original and generated weather variables as predictor variables.

2. to perform a comparative study of relative efficiency, adequacy and performance of each of these crop forecasting models evolved and to select the 'best' most promising and plausible crop forecasting model for the purpose of future use in predicting the crop yield reliably in advance of harvest.

REVIEW OF LITERATURE

REVIEW OF LITERATURE.

2.1 Introduction.

The food situation of India, with its dependence on weather variability has led to

1. the need to give more serious consideration to the analysis of weather and climatic condition of India as a natural resource.
2. the need for monitoring and interpreting current and immediate weather data in terms of expected crop conditions and crop yields.

With the growing awareness of the importance of forecasting crop yields with the current meteorological data and studying its impact on world food supply, various attempts have been made to utilise and develop statistical models to help in prediction.

2.2 Crop weather models and its classification.

A statistical crop weather model helps in the prediction of crop yield from meteorological records using empherical relations from substantial records of crop yield and weather variables. Crop yield depends upon a number of factors such as

1. agricultural inputs
2. irrigation
3. weather variables
4. biometrical factors

Based on these factors, statistical crop weather models can be categorised into four

1. Forecasting models using 'weather variables" as predictor variables.

2. Forecasting models using 'biometrical characters' as predictor variables.

3. Forecasting models using 'agricultural inputs' as predictor variables.

4. Forecasting models using 'combination of weather variables, biometrical characters and agricultural inputs' as predictor variables.

Thus the "rediscovered" importance of the effect of weather and climate on crop production has brought about numerous research projects and publications dealing with crop weather relationship at different scales. Various statistical and mathematical techniques for analysing these relationship have been used and the term crop weather model has emerged as a popular expression in this type of work.

The persons involved in crop weather modelling are not only agrometeorologists but also plant physiologists, agronomists, plant breeders, ecologists, economists and others. Because of their different academic background, they use different approaches and interpretations in their research and applications.

In order to comprehend and appreciate the approach and trend of various pioneers in this field of forecasting, an elaborate review of literature arranged in chronological order is presented in the next section.

2.3 The dawn of crop weather investigations.

The application of statistical models to the prediction of natural phenomenon began in India in 1909 with Sir Gilbert Walker. His investigation on the forecasting of seasonal rainfall in India, from a knowledge of prior weather conditions over the parts of the globe which affect subsequent weather in India was classical.

Ramdas and Kalamkar (1937) reported that Jacob (1916) was the first to apply statistical methods to study the crop weather relationship in the wheat crop of Punjab. He correlated the areas of matured crops over the years 1887 - 1906 in thirty villages chosen from each of the five tahsils of the Sialkot district with rainfall of the preceeding six months. It was seen that rain in September was found to be beneficial to the autumn crop and considerably so, to the spring crop. He also examined the year to year variation of rainfall by fitting Pearsonian frequency curves and periodic curves. In his second paper "correlation between weather and crop with respect to Punjab wheat" used data relating to the total area sown and gross out turn for the whole of Punjab (1893 - 1927). The meteorological data used were the Punjab rainfall and the Lahore maximum temperature for the period October - March, the wheat season. From the multiple regression equation obtained, the area sown was calculated at the end of October while the gross out turn per unit area was calculated at the end of March. These foecast would be known earlier than the official estimates drawn up from local reports.

The value of systematic work on the subject of crop weather relationship, was stressed by the 'Royal Commission' in 1932 when a section of Agricultural Meteorology was commenced at the Meteorological Office, Poona under the auspices of the 'Imperial Council of Agricultural Research'.

In 1945, the Indian Council of Agricultural Research (ICAR) launched an All India Co-ordinated Crop Weather Scheme (AICWS). Under this scheme, specialised meteorological observatories were set up for the systematic recording of crop weather observations on paddy, wheat, jowar etc. The objective of the scheme was to formulate the effect of different growth factors on the growth and yield of crops under observations.

2.4 Studies conducted in relation to perennial crops.

1. Coconut

Patel and Anandan (1936) investigated the relationship between rainfall and yield of coconut by conducting a study which pointed out that crop yield in any particular year is influenced by January to April rains for the two years previous to the harvest together with the rains in January - April of the year of harvest. The data utilised were collected at the Agricultural Research Station, Kasargode. The number of rainy days, the total rainfall for different seasons and years were obtained. The yield data utilised in various correlations were collected from 105 regular bearing palms of ordinary tall type and about 25 years old in 1919. The plot has been manured and cultivated more or less in the same manner from year to year and has never been irrigated. It was seen that the maximum correlation of the yield of coconut and various combiantions of rainfall was 0.8104, the combination of rainfall being

X_2 - the total rainfall in January, February and March during the year previous to harvest.

X_3 - the total rainfall in January, February and March during the second year previous to harvest.

Maximum yield of coconut reported from January and April for two years previous to harvest, form the multiple regression equation of the yield with three predictor variables X_1, X_2, X_3; where

X_1 - the total rainfall in January, February, March and April during harvest year.

The multiple correlation obtained was seen to lie very close to the coefficient of correlation for the total rains in the three years during January - April. The non significance of the total as well as partial correlation indicated that the rainfall of one year is not related to the rainfall of another year for the observations made and the total correlation wherever significant were not spurious.

Balasubramanian (1956) surveyed the influence of rainfall on the yield of coconut in North Kerala districts. The yield data were obtained from Pilicode for 26 years and from Kasargode for 29 years. The monthly rainfall data were obtained from the station records for the years for which the yield data were available. It was inferred that

1. the rains received in January influenced the performance of the crop.

2. February rains also appeared to be important at Kasargode, while the March and April rains assumed similar importance at Pilicode.

3. rains in September were essential for coconut at Kasargode, but October and November rains appeared to be essential for crops at Pilicode.

Investigating the influence of weather factors on coconut crop, Marar and Pandalai (1957) concluded that the seasonal differences did not affect the different characters of the plant and that the yield of a particular year was influenced by January to April rainfalls for two years prior to harvest, with the rains during similar period of harvest year.

Pillai and Satyabalan (1960) on studying the seasonal variation on the yield, nut characters and copra content in a few cultivars of coconut growing at the Central Coconut Research Station, Kasargode reported that the yield variation was very high during different seasons. In majority of the cases summer season showed highest yield while the north west monsoon period showed the lowest. Hence they concluded that seasonal variation observed might be the peculiarity of the exotic coconut cultivars.

In an attempt to relate coconut yield with rainfall, Abeywardena (1968) at first defined the term 'effective rainfall'. The rainfall during the critical period of crop development is called effective rainfall and at times this critical period fairly covers as much as one year or more, especially for coconuts. Thus the critical period was divided into sub periods within which the external environment was more or less uniform and weightage was given to these sub periods as factors influencing the crop was determined using multiple regression technique. It was shown that although the whole year previous to harvest is equally moisture sensitive from the point of view of the stage of crop development, different sub periods of the year showed modified moisture sensitiveness as a result of differences in day lenght, humidity, temperature and their interaction.

Rao (1984) attempted to study the relationship between the annual coconut crop yields and annual rainfall trends using twenty years moving average for the region of Pilicode, North Kerala. The twenty years moving averages of annual rainfall and coconut yields were used to analyse the relationship between them. It was found that both high rainfall during the months of June, July and August, as well as absence of post and premonsoon showers adversely affect the subsequent years coconut yield in the Pilicode region.

2. Oil Palm.

Ong (1982-a) exploratory identification analysis (EIA) as a systematic and objective method of determining the relationship between oil palm bunch yields and changes in rainfalls and dry spells. Monthly oil palm bunch yields were related with monthly reainfall and dry spells as back as 42 months before harvest through a series of correlations and then re-evaluated through a series of partial correlation.

Ong (1982-b) forged ahead with his (EIA) and applied it in determining the relationship between oil palm monthly bunch yield to temperature and sunshine of various months before harvest.

3. Tea

The mean value of rainfall,relative humidity, sunshine hours, temperature were tried as predictor variables in the investigation conducted by Sen et. al. (1966) on the influence of climatic factors on the yield of tea in Assam. A separate analysis was undertaken for each of the early, main and late crops. In their study, time varibles were added as predictor variables for changes in the growth rate of tea plants as it aged. Later on he used the logarithm of rainfall instead of rainfall, which proved to be more beneficial when rainfall was low.

On reviewing the climatic requirements for maintaining the growth of tea plants, Carr (1972) found that long sunshine hours were essential for maximum yield if the nutrient status of tea was adequate as long as other factors such as excessive air, leaf temperature and low air humidity did not become scarce.

According to Devanathan (1975) the growth of plants is controlled by the availability of photosynthesised carbohydrates. Since both rainfall and sunshine are needed for photosynthesis, an emphrerical expression was proposed which relates the vegetative growth to the product of rainfall and sunshine hours over a specified period. The data for tea yield from constant trial plots in Malawi showed that the yield was strongly correlated with the product rainfall per month (R) and average daily hours of sunshine per month (S) for the previous month showed a straight line passing through the origin. Thus the empherical weather parameter RS appeared to be suitable for the study of vegetative harvest.

Mustafi and Chaudhari's (1981) paper develops stochastic process for the monthly tea crop production as functions of stochastic variables like past values of monthly tea crops production and also both past and current values of meteorological parameters (rainfall and Penman's evaporation records). This involves generation of regression polynomial optimal complexity through the use of a heuristic method refered to as a multilayer group method of data handling which provides prediction of tea crop production a month ahead of the crop's picking. It helps to determine the optimal level of precipitation needed for a possible desired level of tea crop production.

2.5. A Brief Review of the literature regarding short duration crops.

2.5.1 Cereals.

1. Corn.

The joint effects of rainfall and maximum daily temperature on the yield of corn crop were investigated by Stacy et. al. (1957). In their work, the maximum daily temperature and rainfall averaged by five day period for 18 periods during each growing season of a 38 year span were related to the corn yields using a set of second degreee orthogonal polynomials as regression integrals. Results indicated that high temperature near the end of growing season were beneficial to crop yields if the rainfall was adequate. When no rains occurred high temperature caused great damage to the crop yield in the first of June.

The objective of the study conducted by Runge (1968) was to show how maximum daily temperature and rainfall interact at various times during the growing season and effect the corn yield. Rainfall and temperature during the growing season were correlated with corn yield under constant management for the 54 years period 1903-1956 at Urbana. Maximum temperature and rainfall have a large effect on corn yield from 25 days before to 15 days after anthesis. June 30th. to August 8th is the average calender interval for this portion of growing season at Urbana. The maximum effect of temperature and rainfall on corn yield occurs approximately one week before anthesis and remains at a high level one week to either side of the maximum. These models also indicated that high temperature between 32.2 ^{o}C and 37.8 ^{o}C are beneficial to corn yield if moisture avaiable to the plant is adequate. Fisher's polynomial technique, as adapted by Hendrick's and Scholl (1943) was used in studing the rainfall temperature yield relationship. He used a fourth degree multiple regression equation with nine generated variables. In their prediction models the following assumptions were introduced.

1. A unit of maximum temperature or a unit of rainfall has the same effect on crop yield for the average temperature or total rainfall above and below average, but in opposite directions.

2. The total effect on the yield is directly proportional to the number of units of maximum temperature or units of total rainfall above and below average.

3. The effect on crop yield in each period is independent of the effect in any other time period.

In his studies Thomsom (1969) used multiple curvilinear regression along with a time trend to evaluate the influence of various weather variables on crop yield. The influence of weather was seperated from the influence of technology on the yield of corn by the use of time trend for technological and multiple cuvilinear regression for weather variables in five corn belts states of USA. The weather variables accounted for most of the variation from the time trend. One of the criticism of such a technique was that there is insufficient numbers of years of observations to provide the number of desirable degrees of freedom.

2. Jowar.

On examination of 9 years data for the crop of wheat, jowar and cotton at Dharwar Research Station, Mallik (1958-a) found that in two years when the wheat yield was very low from rust attack, the number of hours of sunshine days during November was abnormally low. On the basis of comparison of rainfall during growing season in 2 years of good harvest with wheat in two years of poor harvest it was seen that jowar crop at Dharwar is rather susceptible to excessive rainfall during the growing period. It was further suggested that the spell of cloudy and rainy weather extending over three consecutive weeks during growing season of cotton appeared to create condition favourable to pests.

Mallik (1958-b) made a subsequent study of the height of the yield at kharif jowar in relation to rainfall during vegetative period by attempting a more elaborate analysis of 10 year data relating to jowar from 5 stations. It was postulated that the optimum amount of rainfal during the growing of jowar was approximated by the amount of rainfall and its distributiom in each of 12 weeks prior to ear emergence. The correlation coefficient was estimated between

1. height and yield.

2. percentage of deviation of a dural weekly rainfall during the growing period in each year from the rainfall in corresponding weeks of optimum year and percentage deviation from the maximum height.

3. deviation in rainfall for the year of optimum yield and deviation from the optimum yield.

3. Rice.

Das <u>et.</u> <u>al.</u> (1971) evolved prediction equation for forcasting the yield of autumn paddy in Mysore State using weather variables with the help of multiple linear regression analysis. In coastal Mysore restricted rainy days during July to September and frequency of drought and floods in August and September were principal weather factor having significant effect on yield. In the interior Mysore, June and September rainfall had significant effect on yield. By testing the formula for the yield from 1965-1968, it was found that they agreed well with reported yields.

Murata (1975) reviewed the statistical and simulation studies as the effect of climatic factors on rice yield in Japan and carried out correlation studies at various location in the past half century. It was concluded that the most important and limiting climatic factor for rice yield was solar radiation, while it was mean air temperature during the same period in the northern region of Japan.

The method of analysis adopted by Appa Rao et. al. (1978) for forecasting the rice yield in India from weather parameters at Marathwada, Rayalaseema, Gujarat and Himachal Pradesh was similar to the analysis done by Bedekar et. al. (1977). They all used six variables including the variable of technology trend because of the recent advances in the field of agricultural technolgy like use of chemical fertilisers (N,P,K), better irrigation and drainage facilities, control of pests and diseases, better seeds, improved agricultural practises etc, have resulted in sharp rise in the crop yield. The increase for all these factors is called `Technological Trend' which was more evident in the sixtieth decade. On plotting yield Vs year technological trend was noticed in the yield figures of Marathwada from 1975-76, for Rayalaseema from 1960-61, for Himachal Pradesh from 1951-52 and Gujarat from 1952-53.

A suitable statistical methodology was developed by Agrawal (1980) for forecasting the yield of rice in Raipur district using the yield data of 25 years and weekly weather variables - maximum temperature relative humidity, total rainfall and number of rainy days. Two models were found suitable. In the first, weighted average of weekly weather variables and their interaction using powers of week numbers as weights were used. The respective correlation coefficient with yield in place of week number was taken as the second model. The stepwise regression technique was followed for obtaining the forecasting equation. This stepwise regression was used to select singnificant generated variables for the 2 models. Further analysis was done using the significant generated variables. To study the consistency of the forecast models, simulated forecast of subsequent years, not included for obtaining regression equation were worked out.

Rupakumar and Subramanya's (1984) analysis of the crop weather relationship revealed that maximum temperature and relative humidity during the vegatative and flowering phases have a profound influence on the yield of rice. A second degree multiple regression equation involving relative humidity during the vegetative and flowering period has been developed for forecasting purposes. Synoptic systems over the area during crop yield affecting rice yield were identified.

4. Wheat.

The influence of weather on wheat yield at Dharwar was analysed by Ramamurthy and Banerjee (1966) adopting a curvilinear regression analysis of weather variable using successive approximation technique developed by Ezekiel and Fox (1959).

In his paper Sreenivasan (1974) employed regression integral technique of Fisher (1924) to evaluate the influence of rainfall on wheat grown at Jalgaon and Niphad (Maharashtra State) for a period of 22 years. These studies supported the current views of physiologists and agronomists and concluded that the pattern of response was similar at the 2 stations and the two varieties.

A simulation model approach for relating effective climate to winter wheat yield on the Great Plains was brought about by Bridge (1976). He spanned over 12^{o} latitude on the Great Plains and related Kharkov winter wheat yield at four locations to climatic parameters. For each location a stepwise multiple regression technique was used to relate winter yields to climatic parameters generated by constant rust zone (CRZ) water budget and expanding root zone (ERZ) water budget. It was found that

1. compared to those for CRZ model, the multiple linear regression using ERZ model parameters explained an average of 12% more of the total variation in the winter wheat yield.

2. the regression employing only potential evapotranspiration and precipitation variable explained an average of 63% less of variation in winter wheat yield compared to the regression formed with ERZ model parameters.

Bodekar et. al. (1977) developed a regression equation to forecast rabi wheat yield for the meteorological sub divisions Madhya Pradesh, Maharashtra, Rajasthan (east), Gujarat region and Himachal Pradesh. The yield has been taken as dependent variable where as the different weather elements were the independent variables in the equations. According to this method, the mean crop yield for a particular sub-division was first linearly correlated with different weather elements for different overlapping spelles ranging from 7-60 days. Those spells which gave high correlation called sensitive periods were selected. Different combinations of the sensitive periods for different elements were then selected and subjected to multiple correlation analysis with yield as the dependent variable. After numerous permutation and combination, that combination of meteorological parameters was selected which gave high and significant multiple correlation. The individual parameters in the combination was seen to satisfy various statistical tests at the 5% confidence level.

2.6 Seasonal crops.

1. Cotton.

The correlation between weather factor and final estimates of the condition figures of cotton in Dharwar district was worked out by Ramakrishnan (1938). Kumpta is an unirrigated chief variety of cotton sown in the first week of August and therefore the weather factor required to be studied to cover the period from August to March. According to Fisher (1924), to eliminate the effect of economic and physical factors progressing with time, the method of partial correlation between any two series of annual figures treating each series as a function of time and eliminationg the time variables can be adopted. Then third degree parabolas was fitted to the series and the values of the statistical constant and coefficient of correlation with 'condition figures' were found for August rainfall, September rainfall and January maximum temperature. Using these three factors the coefficient of multiple correlation was found which was significant. The condition figures were forecasted with considerable confidence by the end of January i.e. 2 months before harvest, rainfall should be adequate in August and September and temperature low in the month of January.

2. Groundnut.

While conducting an investigation on the occurance of drought at Hebbal, Suryanarayana et. al. (1971) studied the relationship between groundnut yield and rainfall pattern at Hebbal and Bangalore for the period 1957-1966. To explain the variation in the yield, qualitative aspects of rainfall were studied through the parameters namely coefficient of variation of rainfall percentage, the number of rainy days and severity of dry spell. Simple correlation of these parameters with the crop yield revealed importance of qualitative aspects of rainfall also and multiple correlation of these qualitative parameters with yield revealed that 50% of the yield variation in these four factors. Finally it was concluded that the yield of groundnut depended not only on the amount of rainfall but also on the pattern and distribution of rainfall and the stage at which the dry spell occured.

3. Jute.

In Rao's study (1980) on the effect of rainfall and temperature on the yield of tossa jute, the maximum daily temperature and rainfall averaged for 20 weekly periods during the growing season of 1960-1977 were seen related to the fiber yield of tossa jute. Second degree orthogonal polynomial were used as regression integrals. These weather factors explained 87% variation in yields. The maximum effect of temperature and rainfall on yield was observed at about 75 days after germination. Temperature higher than 36 ^{o}C gave positive yield response at all levels of rainfall. Rainfall between 45-100 days of crop age was beneficial to crop yield.

4. Soybeans

Thomson (1970) broadened his views by using multiple curvilinear regression analysis to measure the influence of weather on the yield of soybeans. A linear time trend was introduced to measure the influence of technology , as done in his previous study. The highest yield has been associated with warmer than normal temperature in June but with cooler than normal temperature in July and August. The high yield has also been associated with normal precipitation from September through June and above normal rainfall in July and August.

5. Sugarcane.

Sarkar (1965) suggested that use of method of successive graphic approximation to examine the influence of prevailing weather on yield of sugarcane crop at Poona. It was found that the weather during the tilling phase accounts for 50% of the variaion in the yield.

2.7 A study of crop weather relationship

Mallik <u>et. al.</u> (1960) conducted a preliminary study on crop weather relation. Here analysis was done pertaining to the data of cotton crop from 12 stations. The stations were pooled into two groups on the basis of rainfall in the reproductive period to get sufficient number of observations for studying correlation coefficient between

1. different growth features and yield
2. meteorological factors and some growth features.

The problem posed by pooling of observation could be overcome once sufficient number of observations were available for a particular variety. This kind of analysis was valuable especially when there was no well formulated hypothesis on the precise nature of crop weather relationship.

Gangopadhyaya and Sarker (1964) reported that curvilinear study could be satisfactorily used to bring out a series of crop weather relationship which were not observable on the surface and to provide a basis for estimating the probable effects of new combinations of independent factors upon dependent ones.

Sreenivasan (1972) carried out comparative analysis of relative performance of two statistical methods and brings out the slow continous change in the response of crop yield to the weather patttern experienced by the cultivated soil and crop and two regression function in which the weather pattern was subjected to continous screening to obtain a few well defined weather periods of significance to the soil and crop. It was found that in the case wheat crop at Jalgaon and Niphad region, the regression function had better multiple correlation coeficient than the regression integral. Sreenivasan reasoned that it might be due to the differential response of some of the adjacent hypothesis of crop and changing soil characteristics to the weather variable.

As a consequence of these studies indicating that daily plant growth rate can be used to establish specific numerical growth environmental relationship Haun (1974) initiated that these relationships may be used in prediction of yields. The design of a prediction system was based on the hypothesis that plant growth rate is correlated with yield. To ensure accessibility of sufficient data, environmental variables were limited to temperature and precipitation . Significant lag were found in plant response to environmental variables. Length of the lag periods also changed during seasons. Thus two prediction equations were used to accomodate these changes and they were applied to temperature and precipitation records. Resulting cumulative growth values and data representing pre-season moisture conditions were used as independent variables on which yield was regressed to provide a prediction equation for yield.

The technique adopted by Dyer and Gillooly (1977) to describe crop weather relationship was a stepwise linear regression method. The study set out to show that the useful structural equation could be obtianed for a crop in Iceland. The current years hay yield had a significant structural relationship with the mean cold season temperature, application of nitrogen and mean warm season temperature. It was found that when the previous years yield was added to as a predictor, nitrogen apilcation and mean warm season temperature makes no significant contribution to the relationship.

A sensitivity analysis of statistical crop weather models was performed by Katz (1979). The models considered here were of the type developed by Thompson which predicts yields from climatic variables using empherical relations derived from historical yields and weather. Ridge regression is used to perform the sensitivity analysis. The result of this analysis indicated that the estimated coefficients for these models can be quite variable. These results have significant implications concerning

1. appropriate statistical methodology for developing yield models.
2. the limitation inherent in using these models to assess the impact of climatic vatiability or change in food production

Jones' (1982) paper reviews some of the methodology employed for investigating aggregate crop weather relationship together with the problems encountered. It was supported by an attempt to estimate such a relationship from a short data series for Central Nelfork region. A chi-squared test is used to determine the seasonal significance of weather variables which are then subjected to an analysis of principal components. Employing these components as explanatory variables in multiple regression, the utility of approach for exploring the economics of the agricultural climate was assumed.

2.8 Alternate attempts in the field of crop forecasting.

Various other attempts were made in the field of crop forecasting, among which the work done by Saraswathy and Thomas (1975, 1976) for crop forecasting using log. normal diffusion process are worth mentioning.

Saraswathy and Thomas (1975) used log normal diffusion process to forecast crops like tea, rice, tapioca, coconut, pepper, cashewnut. A log normal model was fitted to the data on the production of the crops. It was found that the models gave satisfactory fit to the data. Estimate of production for the period 1975 76 was obtained using these models. Tinter and Patel (1965) applied log normal model to the data on national income of India using the government expenditure as the exogenous variable. Tinter and Patel (1969) utilized the same model to explain the trend per hectare yield of crops like rice, wheat, sugarcane taking the proportion of irrigated area under crop as exogeneous variable.

The second paper published by Saraswathy and Thomas (1976) dealt with a similar method to explain the trends in the production of crops as mentioned above. It was reported that the coefficient of determination was high and forecast values were very satisfactory. The log normal diffusion model offered a close fit to the data and hence these models could forecast the pre harvest production of crops for the periods which were not very far removed from the year 1973-'74.

2.8 Review of weather forecasting models with reference to rainfall.

The vital role played by rainfall in any crop weather relationship is clearly evident and hence to understand the characteristics of this phenomena, various studies were conducted. In the recent past effort have been made to gather all information about its distribution, frequency and forecast facilities.

Fisher (1924) established that it is the distribution of rainfall during a season than its total amount which influences crop yield. The distribution of rainfall depends on the sequence of wet and dry spells over a period of time and their occurance can be regarded as a series of Bernoullian trials. The pattern of occurance of rainfall was investigated by fitting data over a period of time during which the rainfall has a significant effect on the growth of a particular crop.

Gabriel and Neumann (1962) studied the pattern of occurrance of rainfall at Tel Aviv with the help of Markov chain model. They described the occurrance and non occurance of rainfall by a two state Markov chain - a dry date denoted by state 0 and a wet date denoted by state 1.

On fitting fourth degree orthogonal polynomial curves to the distribution of rainfall at Kasargode during 1926 - 1950 for each year, Lakshmanachar (1965) found that

1. average weekly rainfall had a tendency to increase as the linear component was positive.

2. 75% of the rainfall was from mid May to mid September while the remaining quantity was distributed over the other nine months.

3. there was every certainity of the occurrance of rainfall during the week 23rd - 30th, while during the first 14 weeks probability was very low.

The reliability analysis of rainfall during crop growing season in Bangalore and Kolar districts in Karnataka was conducted by Rao and Rao (1968).

Singh and Pavati (1968) investigated the use of rainfall probabilities in agricultural and planning. The montnly rainfall data of Amaravathi and Coimbatore for 39-40 were obtained. From experience, the frequency distribution are in general skew and hence mean does not give a true picture of the situation. Various transformations were used to remove skewness in the frequency distribution after which values B_1, B_2, mean and standard deviation were calculated for each month over the available number of years. These, together with the appropriate t values provide the confidence limits of the monthly rainfall on the new scale. Thus the monthly and annual rainfall probability together with monthly confidence limits were worked out. It was seen that at Amravathi, the lower limit of about 127 mm of rainfall in July called for urgent measures for draining out in the field preventing water logging. At Coimbatore, supplementary irrigation should be given during the months with very low limit of rainfall.

Basu (1971) conducted fitting Markov chain model for daily rainfall data at Calcutta.

Mathematical distribution of rainfall in arid and semi arid zones of Rajasthan state were developed and analysed by Krishna and Kushwala (1972).

A study of occurrance of rainfall in Raipur district was made by Bhargava et. al. (1973) with the help of a Markov chain model. Data relating to twenty one rain guage stations in different parts of Raipur were collected. A sequence of wet and dry days for each centre were taken where a day is dry if the amount of rainfall was less than 3mm/day and a wet day was its contrary. It was observed that the weather of a day depended on the weather conditions of the previous day. A Markov chain was fitted for each centre and the results indicated that 10 centres have similar pattern of the occurence of rainfall while the remaining were different.

Medhi (1976) utilised the same two state Markov chain model as Gabriel and Newmann (1957,1962) in his study of the occurence and non-occurance of rainfall at Gauhatti, India. The statistical hypothesis testing determining the order of chain, zero or one was carried out using the statistical inference technique for Markov chain developed by Anderson and Goodman (1957).

The objective of Thomas's (1977) paper was to predict the monthly and annual amount of precipitation with number of rainy days at Pattambi Rice Research Station. Based on data relating to monthly and annual amount of precipitation and the number of rainy days at Pattambi for the period 1927-76, point estimates based on different levels of probability for the monthly as well as annual rainfall and number of rainy days have been computed. The mean annual precipitation at Pattambi recorded a value of 2605.3mm, with the standard deviation of the amount of precipitation 536.05mm. The mean number of rainy days per year was 118.24 with a standard deviation of 13.52 days.

Weather conditions at Tamil Nadu Agricultural University, Coimbatore were analysed by Kulandaivelu et. al. (1979). Analysis of rainfall pattern and cropping system in Kinathakkadavu Block, Coimbatore district was carried out by Kulandaivelu et. al. (1979).

Prediction of North East Monsoon at Coimbatore was done by Raj (1979).

Victory and Sastri (1979) analysed the probability of dry spells using the first order Markov chain models and thereby dry spell probabilities were applied to the study of crop development stages effectively.

Nguyen and Rouselle (1981) suggested a stochastic model to determine the probability distribution of rainfall accumulated at the end of each time unit within a total storm duration. The probability of any given number of consecutive rainy hours was determined by first and second order Markov chains. Statistical tests were performed to test the fit of the Markov Model to the sequence of wet hours. By using the stochastic model developed a storm profile was chaacterised in terms of the time of occurance of the storm, total storm depth, probability estimates of accumulated rainfall at the end of each time unit within the total storm duration.

Individually Nguyen (1982) developed a stochastic model to determine the probability distribution of an unbroken sequence of consecutive hours of rainfall amount at the end of each hour within a total n-hour storm duration. A general theoretical methodology has been proposed that has greater flexibility for characterising the temporal pattern of rainfall than previously available. Using the methodology a temporal storm pattern can be characterised in terms the total storm duration, the total storm depth and the probability of accumulated rainfall at the end of each time unit within the storm.

Suryanarayana and Krishnan (1982) ananlysed theoritical distribution of rainfall accumulated during 2 weeks, 4 weeks, 6 weeks etc upto 30 weeks from the commencement weeks of growing season for each individual year at Bangalore region, during the period of 1907-1977. It was found that accumulated rainfall was not normal for second and fourth weeks, also non-normality was found for 10 week and 14-28 weeks respectively.

Bhagavan Das and Ramalingam (1983) investigated monthly and annual rainfall pattern at Pondicherry and the seasonal rainfall at Pondicherry was analysed by Raju et. al. (1983)

Manohar and Siddappa (1984) carried out a study of weather spells and weather cycles at Raichur district using first order Markov chain model. The daily rainfall data for 59 years from 1917 to 1975 for the monsoon months at Raichur were used to fit the first order Markov chain model. It was reported that the first order Markov chain model seemed to fit better for the wet spells than dry spells as judged by the Chi-squared tests.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Materials.

The present study of empherical statistical crop weather models for the yield of cashew crop was carried out for the Cashew Research Station, Madakkathara, Trichur. This station is located at an altitude of 23 meters above mean sea level (MSL) and is situated between 10° 32" N latitude and 76° 16" east longitude. Geographically it falls in the humid climatic zone. The soil in this area could be categorised as the laterite type.

The data for the present investigation was obtained from the Cashew Research Station, Kerala Agricultural University, Madakkathara. The plantation consists of 1044 trees planted in 1973 of which 405 trees were subjected to NPK trials. The remaining 639 trees were treated uniformly from which a sample of 240 trees were utilized for the present study. This sample of 240 trees could be further classified variety wise and as such 16 different varieties each having a total of 15 trees of cashew could be registered. They were

1. BLA - 139 - 1
2. Ansur - 1
3. K - 27 - 1
4. Sawantwadi
5. K - 10 - 2
6. T - 56 of BLA
7. M 6/1
8. T - 40 of BLA

9. M 10/4

10. M 76/4

11. T - 1 of BLA

12. T - 273 of BLA

13. H - 4 - 7

14. Vengula - 37 - 3

15. BLA - 256/1

16. Vengula - 36 - 3

The yield data of these varieties were collected for a period of ten years i.e. from 1976-'77 to 1985-'86.

The meteorological variables considered in this study were

1. Maximum temperature (^{o}C)

2. Minimum temperature (^{o}C)

3. Rainfall (cms)

4. Sunshine (hours)

The monthly data regarding these variables were collected from the Meteorological Observatory, Vellanikara for a period of 11 years is from 1975 - 1985

3.2 Methods.

In the life span of a crop, it is noticeable that weather variables have a profound infuence on its yield and affects it differently at different stages of development. The impact of these weather variables depends on.

1. the magnitude of the weather variable

2. the distribution pattern of these weather variable over the crop season.

These two conditions necessitate the division of the whole crop season into peroids or effective crop season. An effective crop season is defined as the length of the time interval in which the value of the weather variable in that interval are considered to have actual and significant influence on the crop yield.

The cashew tree is perennial in nature. The young cashew sapling planted in the month of July starts its growth with the onset of the rains in October. In due course of time it grows into a tree and on maturity commences flowering during the month of December. The nuts develop and are ready for harvest from the month of February to June.

The flowering period tends to be the crucial stage, while thinking along the lines of yield and it is noticed that the months from September to March have significant influence on factors attributing to yield. Further scrutiny reveals that the rainfall in the months of December, January and February while sunshine and temperature in the months of September, October, November were the trend setters of the yield.

On the basis of the above facts, the effective crop season in this study is taken as six months prior to harvest and based on the influence of these months on yield, they are further divided into four periods or seasons as given below:

1. December, January, February

2. September, October, November

3. Rainfall from December, January, February and temperature and sunshine from September, October, November

4. September, October, November, December, January, February

3.3. Development of models for studying crop weather relationship.

The earlier works undertaken in this regard was confined to simple correlation and regression studies. The first step towards comprehensive analysis of crop weather relationship was the application of multiple regression technique.

3.3.1 Forecasting models with one weather variable.

Let (O,M) be the crop season of a crop over which the effect of a weather variable X is to be investigated. The crop season (O,M) is at first divided into n equal parts or periods after which the multiple regression equation of yield response Y upon the different magnitude of weather variable X at the w^{th} period is illustrated as

$$Y = A_o + \sum_{w=1}^{n} A_w X_w + e \quad \ldots\ldots (1)$$

where

Ao = constant

Aw = linear effect of one unit change in weather variable on the crop yield at wth period and are estimated by the method of least squares.

X_w = value of weather variablr at w^{th} period

As $X_1, X_2, X_3 \ldots X_n$ denotes the value of the variable in different periods, n is likely to be large. In such a situation, a large number of constants have to be evaluated from the data. This will require a long series of data for precise estimates of constants, which may not be available in practise.

Fisher (1924) was the first to tackle this problem. He assumed that the effect of change in weather variable in successive weeks would not be an abrupt or erratic change but an orderly one that follows some mathematical law. He assumed that these effects are composed of the terms of a polynomial function of time.

Assuming that the values of the weather at the w^{th} period be expressed in terms of orthonormal function of time. X_w can be expressed as

$$X_w = p_o [f_o(w)] + p_1 [f_1(w)] + \ldots + p_m [f_m(w)] \quad (2)$$

where p_k's are the distribution constant of X_w. The function $f_k(w)$ is a polynomial of the m^{th} degree ($k = 0,1,2,\ldots m$).

Since the effect of change in weather variable in successive periods could not be an orderly one following some mathematical law, it can be assumed that the A_w can also be expressed as a polynomial

$$A_w = a_0 [f_0(w)] + a_1 [f_1(w)] + a_2 [f_2(w)] + \ldots + a_m [f_m(w)] \quad \ldots\ldots\ldots\ldots(3)$$

where $a_0, a_1, a_2, \ldots a_m$ are constants.

Substituting (2) & (3) in (1) and utilising the properties of orthogonal or normalised functions fk(w), he obtained

$$Y = A_o + \sum_{k=0}^{m} a_k p_k + e \quad \ldots\ldots\ldots\ldots (4)$$

Fisher developed this model for examining the influence of rainfall on wheat at Rothamsted, England. This model takes into account not only total rainfall during certain period but also the manner in which rainfall was distributed over the crop season, under consideration. Fisher suggested to use m = 5 for most of the practical situations. In such an equation the number of constants to be evaluated will remain 7, no matter how finely the season is divided.

Fisher's crop weather model follows two assumptions, namely the expressibility of X_w, magnitude of weather variable and A_w, the effect on crop yield in terms of p_k, the polynomial function.

Eventhough the two assumptions may be satisfied in case of annual crops like rice, wheat, sugarcane, ground nuts etc. whose crop seasons are relatively short; the first assumption of expressibility of weather variable X_w

in terms of polynomial function of time, would not be satisfied in case of perennial or plantation crops. This is because the magnitude of the weather variable as far back as one or two years or more from the year of harvest have influence on crop yield.

Therefore, concerning this study we cannot follow Fisher's method of decreasing the number of predictor variables in our forecasting models. An alternate approach was the method offered by Hendrick and Scholl. In this method the crop season (0,M) is divided into finite number of intervals or periods and it is assumed that only the effect of the weather variable at the wth period can be expressed in terms polynomial functions of some variables such as interval or period number w.

3.2.2 Forecasting models with two weather variables.

Hendrick and Scholl (1943) modified Fisher's technique such that they divided the crop season into n weekly intervals or periods and it was assumed that a polynomial of degree k in the variable period or interval number w would be sufficiently flexible to express the relationship. Mathematically it can be expressed as

$$A_w = \sum_{k=0}^{m} a_k w^k$$

Substituting this equation in (1)

$$Y = A_o + [\sum_{k=0}^{m} a_k \sum_{w=1}^{n} w^k] X_w + e \quad \ldots\ldots\ldots\ldots\ldots(5)$$

Let

$$Z_k = \sum_{w=1}^{n} w^k X_w$$

Therefore

$$Y = A_o + \sum_{k=0}^{m} a_k Z_k + e \quad \ldots\ldots\ldots\ldots\ldots(6)$$

In this model, number of constants to be determined reduces to 4, if m = 2 irrespective of n, the number of periods within the crop season.

The crop weather model (1) can be modified for two weather variables, X_1 - rainfall and X_2 - maximum temperature, taking into account their interaction effect as

$$Y = A_o + \sum_{w=1}^{n} A_w X_{1w} + \sum_{w=1}^{n} B_w X_{2w} + \sum_{w=1}^{n} C_w X_{1w} X_{2w} \quad \ldots\ldots(7)$$

where X_{1w} and X_{2w} are the magnitude of the weather variable X_1 and X_2 at the w^{th} period within the crop season (O,M)

As in the crop weather model (5) the effects A_w, B_w and C_w can be expressed as

$$A_w = \sum_{k=0}^{m} a_k w^k$$

$$B_w = \sum_{k=0}^{m} b_k w^k$$

$$C_w = \sum_{k=0}^{m} c_k w^k$$

Substituting these values in (7) we get

$$Y = A_o + \sum_{k=0}^{m} a_k \left[\sum_{w=1}^{n} w^k X_{1w} \right] + \sum_{k=0}^{m} b_k \left[\sum_{w=1}^{n} w^k X_{2w} \right] + \sum_{k=0}^{m} c_k \left[\sum_{w=1}^{n} w^k X_{1w} X_{2w} \right] \qquad \ldots\ldots\ldots(8)$$

Hendrick and Scholl employed this crop weather model, taking m = 2 as quadratic polynomial in period w, on their studies of effect of rainfall, maximum temperature and their interaction on crop yield.

As in the crop weather model (5) the effects A_w, B_w and C_w can be expressed as

$$A_w = \sum_{k=0}^{m} a_k w^k$$

$$B_w = \sum_{k=0}^{m} b_k w^k$$

$$C_w = \sum_{k=0}^{m} c_k w^k$$

Substituting these values in (7) we get

$$Y = A_o + \sum_{k=0}^{m} a_k \left[\sum_{w=1}^{n} w^k X_{1w} \right] + \sum_{k=0}^{m} b_k \left[\sum_{w=1}^{n} w^k X_{2w} \right]$$

$$+ \sum_{k=0}^{m} c_k \left[\sum_{w=1}^{n} w^k X_{1w} X_{2w} \right]$$

........(8)

Hendrick and Scholl employed this crop weather model, taking m = 2 as quadratic polynomial in period w, on their studies of effect of rainfall, maximum temperature and their interaction on crop yield.

3.3.3 Forecasting models with many weather variables.

The basic crop weather model (7) was modified for the purpose of developing crop weather models using many weather variables. A complete second order response surface type model was developed using p weather variables. The original statistical model adpoted for the purpose was as follows

$$Y = A_o + \sum_{i=1}^{p} \sum_{w=1}^{n} A_{iw} X_{iw} + \sum_{i=1}^{p} \sum_{w=1}^{n} B_{iw} X_{iw}^2 + \sum_{i<j}^{p} \sum_{w=1}^{n} G_{(ij)w} X_{iw} X_{jw} + h_o t + e$$

where,

A_{iw} = linear effect of Ith weather variable X_{iw} at the w^{th} period on crop yield.

B_{iw} = quadratic effect of i^{th} weather variable X_{iw} at w^{th} period on crop yield

$G_{(ij)w}$ = effect of two factor interaction of i^{th} and j^{th} weather variable X_{iw} and X_{jw} at w^{th} within the crop season (O,M).

T = trend

Assuming that it would be sufficiently flexible to express A_{iw}, B_{iw} and $G_{(ij)w}$ in terms of polynomials of degree m in the variables of functions $H_1(w)$, $H_2(w)$ and $H_3(w)$ of period number w, we have the following relations

$$A_{iw} = \sum_{k=0}^{m} a_{ik} H_1^k(w)$$

$$B_{iw} = \sum_{k=0}^{m} b_{ik} H_2^k(w)$$

$$G_{(ij)w} = \sum_{k=0}^{m} g_{(ij)k} H_3^k(w)$$

where a_{ik}, b_{ik} and $g_{(ij)k}$ are constants in the polynomials of H_1^k, H_2^k and H_3^k respectively.

Substituting the above three equations in (9) we get

$$Y = Ao + \sum_{i=1}^{p} \sum_{k=0}^{m} a_{ik} \sum_{w=1}^{n} H_1^k X_{iw}$$

$$+ \sum_{i=1}^{p} \sum_{k=0}^{m} b_{ik} \sum_{w=1}^{n} H_2^k X_{iw}^2$$

$$+ \sum_{i=1}^{p} \sum_{k=0}^{m} g_{(ij)k} \sum_{w=1}^{n} H_3^k X_{iw} X_{jw}$$

$$+ h_o T + e \qquad \text{........(10)}$$

Let

$$Z_{ik} = \sum_{w=1}^{n} H_1^k(w)\, X_{iw}$$

$$Z_{ik}' = \sum_{w=1}^{n} H_2^k(w)\, X_{iw}^2$$

$$Q_{(ij)k} = \sum_{w=1}^{n} H_3^k(w)\, X_{iw}\, X_{jw}$$

Hence the equation (10) becomes

$$Y = A_o + \sum_{i=1}^{p} \sum_{k=0}^{m} a_{ik} Z_{ik} + \sum_{i=1}^{p} \sum_{k=0}^{m} b_{ik} Z'_{ik}$$

$$+ \sum_{i=1}^{p} \sum_{k=0}^{m} g_{(ij)k} Q_{(ij)k} + h_o T + e$$

.............(11)

Within the class of complete second order response surface type statistical crop weather models, the above crop weather model (11) is the most general form of crop weather model from which many forecasting models can be derived and brought out for different values of the paramater p, m, n and for different forms of the generated predictor variable depending upon the various functional forms of $H_1^k(w)$, $H_2^k(w)$ and $H_3^k(w)$.

1. If we take

$$H_1^k(w) = H_2^k(w) = H_3^k = w^k$$

$$m = 2 \quad \text{and} \quad b_{ik} = 0 \quad \text{for all } i \,\&\, k$$

the model (11) boils down to the crop weather model used by Hendricks and Scholl (1943), Stacy et. al. (1947) and Rao (1980).

2. If

$$H_1^k(w) = H_2^k(w) = H_3^k = w^k$$

$$m = 4 \quad \text{and} \quad b_{ik} = 0 \quad \text{for all } i \,\&\, k$$

the model (11) reduces to the forecasting model employed by Runge and Odell (1957)

3. If

$$H_1k(w) = H_2k(w) = H_3k(w) = w^k / \sum_{w=1}^{n} w^k$$

$$b_{ik} = 0 \quad \text{for all } i \,\&\, k$$

the model (11) is similar to the forecasting model I of Agrawal et. al. (1980).

4. If

$$H_1^k(w) = r_{iw}^k(1) / \sum_{w=1}^{n} r_{iw}^k(1)$$

$$H_3^k(w) = r_{(ij)w}^k(3) / \sum_{w=1}^{n} r_{(ij)w}(3)$$

$$b_{ik} = 0 \quad \text{for all } i \,\&\, k$$

where $r_{iw}(1)$ is the correlation coefficient of Y with X_{iw} and $r_{iw}(3)$ is the correlation coefficient of Y with the product X_{iw} and X_{jw} at the w^{th} period, in model (11) then it reduces to the forecasting model II of Agrawal _et. al._ (1980) and Jain _et. al._ (1980)

Thus the forecasting model (11) is more general than those models recently considered and it can be expected that this model would render a wider scope and structure of the system of generated predictor variables which are influencing the yield than the other remaining models.

3.4 Forecasting models for the yield of cashew utilised in the present investigation.

The general form of the forecasting models employed in the present study is given by equation (11) from which different forecasting models are derived for different values of the parameters and predictor variables.

Case I.

Let the predictor variables in the general forecasting model (11) be

$$Z_{ik} = \sum_{w=1}^{n} H_1^k(w)\, X_{iw}$$

$$Z'_{ik} = \sum_{w=1}^{n} H_2^{k}(w)\, X_{iw}^{2}$$

$$Q_{(ij)k} = \sum_{w=1}^{n} H_3^{k}(w)\, X_{iw}\, X_{jw}\,, \quad i<j$$

Model 1.

In this.model, the predictor variable in the general forecasting model (11) are

$$Z_{ik} = \sum_{w=1}^{n} w^{k} X_{iw}$$

$$Z'_{ik} = \sum_{w=1}^{n} w^{k} X_{iw}^{2}$$

$$Q_{(ij)k} = \sum_{w=1}^{n} w^{k} X_{iw}\, X_{jw}\,, \quad i<j$$

Model 2.

The predictor variables of the general forecasting model in this model are

$$Z_{ik} = \sum_{w=1}^{n} w^{k} X_{iw} \Big/ \sum_{w=1}^{n} w^{k}$$

$$Z'_{ik} = \sum_{w=1}^{n} w^{k} X_{iw}^{2} \Big/ \sum_{w=1}^{n} w^{k}$$

$$Q_{(ij)k} = \sum_{w=1}^{n} w^{k} X_{iw} X_{jw} \Big/ \sum_{w=1}^{n} w^{k}, \quad i<j$$

<u>**Model 3.**</u>

In this model, the predictor variables for the general forecasting model (11) are constructed as

$$Z_{ik} = \sum_{w=1}^{n} r_{iw}^{k}(1) X_{iw} \Big/ \sum_{w=1}^{n} r_{iw}^{k}(1)$$

$$Z'_{ik} = \sum_{w=1}^{n} r_{iw}^{k}(2) X_{iw}^{2} \Big/ \sum_{w=1}^{n} r_{iw}^{k}(2)$$

$$Q_{(ij)k} = \sum_{w=1}^{n} r_{(ij)w}^{k}(3) X_{iw} X_{jw} \Big/ \sum_{w=1}^{n} r_{(ij)w}^{k}(3), \quad i<j$$

where $r_{iw}(1)$, $r_{iw}(2)$ and $r_{(ij)w}(3)$ are the correltation coefficients of cashew crop yield Y with X_{iw}, X_{iw}^{2} and $X_{iw} X_{jw}$ $(i<j)$ respectively.

Case II

Here the predictor variables in the general forecasting models are constructed as

$$Z_{ik} = \sum_{w=1}^{n} H_1^k(w)\, X_{iw}$$

$$Z'_{ik} = \sum_{w=1}^{n} H_2^k(w)\, X_{iw}^{1/2}$$

$$Q_{(ij)k} = \sum_{w=1}^{n} H_3^k(w)\, X_{iw}^{(1/2)}\, X_{jw}^{(1/2)}, \quad i<j$$

Model 4.

$$Z_{ik} = \sum_{w=1}^{n} w^k X_{iw}$$

$$Z'_{ik} = \sum_{w=1}^{n} w^k X_{iw}^{(1/2)}$$

$$Q_{(ij)k} = \sum_{w=1}^{n} w^k X_{iw}^{(1/2)}\, X_{jw}^{(1/2)}, \quad i<j$$

are the generated predictor variables in the general forecasting model (11).

Model 5.

The generated predictor variable constructed for the general forecasting model (11) in this model are

$$Z_{ik} = \sum_{w=1}^{n} w^{k} X_{iw} \Big/ \sum_{w=1}^{n} w^{k}$$

$$Z_{ik}' = \sum_{w=1}^{n} w^{k} X_{iw}^{(1/2)} \Big/ \sum_{w=1}^{n} w^{k}$$

$$Q_{(ij)k} = \sum_{w=1}^{n} w^{k} X_{iw}^{(1/2)} X_{jw}^{(1/2)} \Big/ \sum_{w=1}^{n} w^{k} \quad , \; i<j$$

Model 6.

This final model adopts the general predictor variables

$$Z_{ik} = \sum_{w=1}^{n} r_{iw}^{k}(1) X_{iw} \Big/ \sum_{w=1}^{n} r_{iw}^{k}(1)$$

$$Z_{ik}' = \sum_{w=1}^{n} r_{iw}^{k}(4) X_{iw}^{(1/2)} \Big/ \sum_{w=1}^{n} r_{iw}^{k}(4)$$

$$Q_{(ij)k} = \sum_{w=1}^{n} r_{(ij)w}^{k}(5) X_{iw}^{(1/2)} X_{jw}^{(1/2)} \Big/ \sum_{w=1}^{n} r_{(ij)w}^{k}(5) \quad , \; i<j$$

where $r_{iw}(1)$, $r_{iw}(4)$ and $r_{(ij)w}(5)$ are the correltation coefficients of cashew crop yield Y with X_{iw}, $X_{iw}^{(1/2)}$ and $X_{iw}^{(1/2)}\ X_{jw}^{(1/2)}$ $(i<j)$ respectively; for the general forecasting model.

3.5 Selection of effective crop season with regard to present crop forecasting model

The effective crop season in case of cashew is taken pertaining to this study, as six months prior to the month of harvest which is believed to have influence on the yield of cashew tree. In other words the magnitude and distribution of weather parameters from September to February are the deciding factors of the yield. Based on this information the meteorological data is divided into four seasons

Season I - December, January, February

Season II - September, October, November

Season III - Rainfall from December, January, February, sunshine and temperature from September, October, November.

Season IV - September, October, November, December, January, February

Thus in Season I, Season II and Season III the values of the parameters in the crop forecasting model are p=4, m=2, n=3 ie. i=1,2,3,4; k=0,1,2; w=1,2,3. In Season IV the parametric values are p=4, m=2, n=6 ie. i=1,2,3,4; k=0,1,2; w=1,2,3,4,5,6

The yield data obtained pertains to sixteen varieties of cashew and six models are to be constucted for each of the sixteen varieties within the four seasons. For simplicity sake abbreviations are made use of based on the following logic

If we are refering to model 1 in the first Season for the first variety of cashew, it is represented as $S1M1.V_1$. Similarly if we are refering to second variety of model 1 in the first season then it is abbreviated as $S1M1.V_2$. $S2M5.V_{16}$ refers to sixteenth variety of cashew of model 5 in the second season. Thus in general, SpMq.Vr refers to the r^{th} variety of cashew of the model q in the p^{th} season.

Proceeding henceforth, in total each variety of cashew illustrates six models in one season. Therefore in one season a total of 96 models are constructed taking into acount all the sixteen varieties. The same logic applies to all the remaining three seasons.

3.6 Generation of predictor variables.

The predictor variables to be generated are first order predictor variables namely Z_{ik} and Z_{ik}' and second order predictor variables $Q_{(ij)k}$, $i<j$. In this study twelve different predictor variables are generated for each Z_{ik} and Z_{ik}', with eighteen generated predictor variables for $Q_{(ij)k}$ $(i<k)$, for a model pertaining to a particular Season. Thus totally 42 predictor variables are considered for each of the proposed model.

From these 42 predictor variables 9 predictor variables having the highest correlation coefficient with yield response are selected as preliminary selected variables. From these preliminary selected predictor variables, the most important predictor variables are then selected by step wise regresssion technique using forward selection procedure [Draper and Smith, 1981] for each of the proposed forecasting models

3.7 Criteria functions for the comparison of efficiencies and performance of the forecasting models

Hockings in 1976 listed out a number of criteria functions based on which the most efficient and plausible crop forecasting models could be selected. These criteria are stated in terms of the behavior of certain functions as a function of predictor variables included in the different crop forecasting models selected through step up regression procedure. Many of these criterian functions are simple functions of residual mean square (RMS) for each crop forecasting model which is assumed to have r parameters including constant A_o and number of observations on crop yield response Y to be s. This investigation employs the following criteria funtions.

1. **Residual mean square (RMS)**

The RMS defined as

$$RMS = MSE = SSE/(s-r)$$

is a measure used to judge the adequacy of a fitted regression equation. Among the several regression equations the one with the smallest value of RMS is usually prefered and this model is selected appropriately

2. Squared multuple correlation coefficient (R^2)

R^2 is an index of goodness of fit of the model: most widely used. It can be viewed as a measure of strength and adequacy of fit, which is usually used to judge the fit of the linear model to a given body of data. It is defined as follows

$$R^2 = SSR/SST = 1 - (SSE/SST)$$

However the statistical significance of R^2 may not give a true picture of the adequacy of the model fitted to a given body of data. Another limitation of R^2 is that for a fixed residul sum of squares, R^2 increases with the steapness of the regression surface.

3. Adjusted square multiple correlation coefficient (Ra^2).

As an alternative to R^2 some users recomended the adjusted multiple correlation coefficient. This procedure is exactly equivalent to looking for the minimum RMS, as an adjustment to remove upward bias when based on small number of observations.

$$Ra^2 = 1 - (1 - R^2).(s-1)/(s-r)$$

4. Total prediction variance (Jr).

Jr arises by computing the total prediction variance over the current data for a given subset of predictor variables and then estimating variance by RMS. Jr is defined as

$$Jr = [(s + r)/(s - r)]\ SSE = (s + r)\ RMS$$

Jr is used when the objective of regression is to predict the future response. But theoretically the criterion function Jr has the drawback of ignorance of bias prediction.

5. Prediction mean square error (MSEP).

Tukey (1967) and Sclove (1971) advocated the use of criterion of MSEP if the objective of the regression analysis is prediction of a future response and estimation of the mean response for a given input. MSEP expressed as

$$MSEP = [(s^2 - 1)/s].[RMS/(s-r-1)]$$

6. Average estimated variance (AEV)

The criterion function called the average estimated variance (AEV) is defined as

$$AEV = r.(RMS)/s$$

This criterion involves averaging the prediction variance over the whole regression region of interest, rather than for just the data points given and using a weight function which attaches more weight to the more 'important' points in the region.

7. **Amemiya prediction criterion (APC)**

Amemiya (1980) developed a criterion function based on prediction mean square error (MSEP) in order to include the consideration of the losses associated with choosing an incorrect model. It is defined as

$$APC = (s+r)/(s-r).(1-R^2).SST/s$$

where SST is total sum of squares. APC is also a reasonable and satisfactory criterion function to be employed in selecting the 'best' fitted crop forecasting models.

8. Akaike information criterion (AIC)

Akaike information measure (criterion) seeks to incorporate in selecting the predictor variable that the divergent consideration to reality. Thus, information criterion involves a statistic that incorporates a measure of precision of estimate and measure of a rule of parsimony in the parametrigation of a statistical crop forecasting model.

Akaike (1978) proposed a modified form of his original AIC. The AIC function in terms of R^2 and SST is defined as follows

$$AIC = (s-r).\ ln[(1-R^2)/(s-r).(SST)] + r.\ ln\ [R^2/r(SST)]$$

From the above discussions on various criteria functions to be employed in selecting the 'best' crop forecasting models, it is clear that the choice of criterion depend very much on how the chosen model will be used.

RESULTS

RESULT

The study conducted on the data collected from sixteen varieties of cashew from the Cashew Research Station, Madakkathara, yielded the following results.

4.1 Statistical analysis of the forecasting models in the four seasons.

The important results from the step up regression analysis on each of the six different forecasting models in the four seasons as proposed in Chapter III are presented in the following sections.

Step up regression technique was adopted for each of the proposed six models, in all the four seasons for each of the sixteen varieties of cashew. Only those models which registered a significant F value in their analysis were chosen for further statistical treatment. The results of the step up regression of the chosen models were illustrated in the following sub sections.

4.2.1 Statistical analysis of the chosen forecasting model under Variety 1

A total of six models were selected under Variety 1. They were four models from Season I and one model from each Season II and Season IV.

a. Season I (Dec, Jan, Feb)

1. $S1M2.V_1$

From the nine preliminary selected variables, seven predictor variables were included in the final crop forecasting model namely Z_{31}', Z_{42}', Z_{43}', $Q_{(13)0}$, $Q_{(23)0}$, $Q_{(24)1}$ and $Q_{(24)2}$. The estimated regression coefficients for these corresponding predictor variables, along with there standard error and computed t value were presented in Table . 1. It was noted that on the basis of R^2 and adjusted R^2 (Ra^2), the adequacy of fitted crop forecasting model was highly satisfactory as R^2 = 0.9899 and Ra^2 = .9546. This showed that 98.99% of the total variance from the mean in yield response Y was accounted for by the predictor variable in the fitted forecasting model $S1M2.V_1$.

The final form of the crop forecasting model $S1M2.V_1$ developed through step-up regression procedure was

$$Y = 20.4684 + 0.0000295\, Z'_{31} + 0.3917404\, Z'_{42} + 0.1126352\, Z'_{43} + 0.1088218\, Q_{(13)0} - 0.1366307\, Q_{(23)0} - 1.0997231\, Q_{(24)1} + 0.7923317\, Q_{(24)2}.$$

2. $S1M4.V_1$

A total four predictor variables were included in the final crop forecasting model, from the nine preliminary selected predictor variables. The four variables were Z_{32}', Z_{42}, $Q_{(13)0}$, $Q_{(23)0}$. The estimated regression coefficient for these predictor variables, along with their standard error and computed t value were presented in Table . 2. Since the R^2 value was 0.8567, 85.67% of the total variation from the mean in the yield response Y was explained by the four predictor variables in the final forecasting model $S1M4.V_1$. A point of interest was that the regression coefficient of these four variables were significant at 5% level.

The final crop forecasting model developed was

$$Y = 1.1865 - 1.0357801\ Z'32 + 0.0737754\ Z42 + 3.202265\ Q_{(13)0} - 3.322208\ Q_{(23)0} .$$

3. $S1M5.V_1$.

Z'_{31} , $Q_{(13)0}$, $Q_{(14)2}$, $Q_{(23)0}$, and $Q_{(24)2}$ are the five predictor variables chosen from the nine preliminary selected predictor variable to be included in the final crop forecasting model. The estimated regression coefficient of these predictor variables, along with their standard error and computed t values were illustrated in Table. 3. It is seen that all the regression coefficients except $Q_{(14)2}$ and $Q_{(24)2}$ were statistically significant at 5% level. Moreover the R^2 explained 85.99% of the total variance from the mean in the yield response in the fitted crop forecasting model $S1M5.V_1$.

The final crop forecasting model was constructed as,

$$Y = 0.5490 + 329.21109\ Z'_{31} - 26.925797\ Q_{(13)0} - 6.6841816\ Q_{(14)2} - 36.51237\ Q_{(23)0} + 8.4259166\ Q_{(24)2}$$

4. $S1M6.V_1$

The only predictor variable selected from the nine preliminary selected variable, to be included in the final crop forecasting model was Z_{32}'. The estimated correlation coefficient with its standard error and computed t value were presented in Table. 4.

The final crop forecasting model was constructed as

$$Y = 2.3609 + 0.6414482\, Z_{32}'$$

b. Season II (Sept, Oct, Nov)

1. $S2M3.V_1$

$Q_{(12)2}$ and $Q_{(14)1}$ were the two predictor variables selected from the nine preliminary selected variables, to be included in the final crop forecasting model. Their estimated regression coefficients as well as standard error and computed t values were presented in Table. 5. It was noticed that both the regression coefficients were significant at 5% level of significance. The R^2 and Ra^2 values signified the adequacy of fit of a linear regression model to the given set of data on these two predictor variables was highly satisfactory and consequently the crop forecasting model $S2M3.V_1$ could be used for future prediction purposes.

The final form of the crop forecasting model was

$$Y = 33.5432 - 0.050802\, Q_{(12)2} + 0.0336214\, Q_{(14)1}$$

c. **Season IV**

1. **$S4M6.V_1$**

$Q_{(34)1}$ was the only predictor variable included in the final crop forecasting model, from the nine preliminary selected variable. The estimated regression coefficient, along with standard error and computed t value were illustrated in Table. 6. The regression coefficient was significant and from the R^2 value it was found that 72.39% of the total variance from the mean in yield response was accounted by the predictor variables in the fitted forecasting model $S4M6.V_1$

The final form of the crop forecasting model $S4M6.V_1$ was.

$$Y = -0.2800 + 0.7695924\ Q_{(34)1} .$$

Table. 1 Step-up regression analysis for the crop forecasting model $S1M2.V_1$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'	b	0.0000295	0.0008784	-0.0336
$Q_{(23)0}$	$g_{(23)0}$	-0.1366307	0.04811918	-2.8394
Z'_{43}	b_{43}	0.1126352	0.3926034	0.2869
$Q_{(13)0}$	$g_{(13)0}$	0.1088218	0.03521734	3.09
$Q_{(24)2}$	$g_{(24)2}$	0.7923317	0.23245329	3.4086
Z'_{42}	b_{42}	0.39174044	0.43785037	0.8947
$Q_{(24)1}$	$g_{(42)1}$	-1.0997231	0.2731804	-4.0256

$S = 10$ $R^2 = 0.9899$ $Ra^2 = 0.9546$

$A_0 = 20.4684$ $t_{5\%,2} = 4.303$

Table. 2 Step-up regression analysis for the crop forecasting model $S1M4.V_1$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{32}	b_{32}	-1.0357801	0.2548083	-4.0665*
$Q_{(23)0}$	$g_{(23)0}$	-3.322208	1.2309828	-2.6988*
$Q_{(13)0}$	$g_{(13)0}$	3.202265	1.1126004	2.8782*
Z_{42}	a_{42}	0.0737754	0.0257918	2.8604*

$S = 10$ $R^2 = 0.8567$ $Ra^2 = 0.7421$

$A_0 = 1.1865$ $t_5 = 2.571$

Table. 3 Step-up regression analysis for the crop forecasting model $S1M5.V_1$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{31}	b_{31}	329.21109	90.298986	3.6458*
$Q_{(23)0}$	$g_{(23)0}$	-36.51237	10.687984	-3.4162*
$Q_{(13)0}$	$g_{(13)0}$	-26.925797	7.3958148	-3.6407*
$Q_{(24)2}$	$g_{(24)2}$	8.4259166	4.1994237	2.0064
$Q_{(14)2}$	$g_{(14)2}$	-6.6841816	3.3797254	-1.9777

$S = 10$ $R^2 = 0.8599$ $Ra^2 = 0.6848$

$A_0 = 0.5490$ $t_4 = 2.776$

Table. 4 Step-up regression analysis for the crop forecasting model $S1M6.V_1$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{32}	b_{32}	0.6414482	0.245484	2.6130*

$S = 10$ $R^2 = 0.4605$ $Ra^2 = 0.3930$

$A_0 = 2.3609$ $t_5 = 2.306$

Table. 5 Step-up regression analysis for the crop forecasting model S2M3.V_1

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(14)1}$	$\varepsilon_{(14)1}$	0.0336214	0.0123252	2.7279*
$Q_{(12)2}$	$\varepsilon_{(12)2}$	-0.050802	0.0206901	-2.4554*

S = 10 R^2 = 0.6501 Ra^2 = 0.6063

A_0 = 33.5432 $t_{5\%,7}$ = 2.365

Table. 6 Step-up regression analysis for the crop forecasting model S4M6.V_1

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$\varepsilon_{(34)1}$	0.7695924	0.1680232	4.5803*

S = 10 R^2 = 0.7239 Ra^2 = 0.6894

A_0 = 0.2800 t_8 = 2.306

4.2.2 Statistical analysis of the chosen forecasting models for Variety 2

Fourteen forecasting models were selected under this variety. They were three models from Season I, four models from Season II, four models from Season III and three models from Season IV.

a. Season I (Dec, Jan, Feb)

1. $S1M3.V_2$

This forecasting model belonged to the model three square model as developed in Chapter III.

Z_{22} was the only predictor variable included in the final crop forecasting model, from the nine preliminary selected variables. Table 7 illustrates the estimated regression coefficients of the predictor variables along with its standard error and computed t value. The regression coefficient was found to be significant.

The final form of the crop forecasting model was

$$Y = 8.7944 + 0.5438892\ Z_{22}$$

2. $S1M4.V_2$

This forecasting model belonged to the category of square root models as developed in Chapter III.

From the nine preliminary selected variables, six predictor variables were finally chosen to be included in the crop forecasting model. They were $Q_{(13)0}$, $Q_{(13)1}$,

$Q_{(23)0}$, $Q_{(23)1}$, $Q_{(24)1}$ and $Q_{(34)0}$. The estimated regression coefficients along with their standard error and computed t values were presented in Table. 8. From the R^2 and Ra^2 value it could be concluded that the adequacy of fit of a linear regression model to the given set of data on these six predictor variables was also highly satisfactory but the use of forecasting model $S1M4.V_2$ for future prediction of yield in advance of harvest would be adjuged on the basis of criteria measure corresponding to this model.

The final form of the crop forecasting model $S1M4.V_2$ developed through step-up regression technique was

$$Y = 0.8906 - 0.427498\, Q_{(13)0} + 0.8602794\, Q_{(13)1} - 0.0294396\, Q_{(23)0} - 1.1534425\, Q_{(23)1} + 0.0168138\, Q_{(24)1} + 1.497314\, Q_{(34)0}$$

3. $S1M5.V_2$

This forecasting model belonged to the category of square root models as developed in Chapter III.

$Q_{(23)1}$, $Q_{(34)0}$ and $Q_{(23)1}$ were the three predictor variables included in the crop forecasting model from the nine preliminary selected variables. Table. 9 illustrates the estimated regression coefficient in combination with their standard error and computed t value from the table, it was evident that all the regression coefficients of the predictor variables were statistically significant at 5%. From the R^2 value it was found that 83% of the total variance from the mean in yield response was accounted for the predictor variable in the fitted forecasting model $S1M5.V_2$. Thus it could be concluded that adequacy of fit of a linear regression model to the given set of data on these three predictor variables was also satisfactory and could be hence used for future purpose of predicting yield in advance of harvest.

The final form of the crop forecasting model $S1M4.V_2$ developed through step-up regression technique was

$$Y = 0.7318 - 3.036694\, Q_{(23)1} + 1.3181097\, Q_{(34)0} - 4.3626923\, Q_{(34)1}$$

b. Season II

1. $S2M1.V_2$

This forecasting model belonged to model one developed in Chapter III as a complete second order response surface type crop forecasting model (square model) Z_{43}, Z_{42} and Z'_{42} were the three predictor variables included in the final crop forecasting model from the nine preliminary selected variable. Table. 10 exhibited the estimated regression coefficients along with their standard error and computed t value. It was noticed that except Z_{42} the other two regression coefficients were statistically significant at 5% level of significance. With an R^2 value of 0.8157, 81.57% of the total variance from the mean yield response could be accounted for by the predictor variable in the fitted forecasting model $S2M1.V_2$

The final form of the forecasting model developed through step up regression technique was

$$Y = 38.9794 + 0.9844870\ Z_{42} + 0.6058526\ Z_{43} - 0.199961\ Z'_{42}$$

2. $S2M2.V_2$

This forecasting model belonged to model two developed in Chapter III as a complete second order response surface type crop forecasting model (square model)

The three predictor variables included in the final crop forecasting model from the nine preliminary selected variable were Z_{42}, Z'_{42} and Z'_{43}. Table. 11 exhibited the estimated regression coefficients along with their standard error and computed t value. It was noticed that all the three regression coefficients were statistically significant at 5% level of significance. From the R^2 value it could be concluded that the adequacy of fit of a linear regression model to the given set of data on these predictor variables was satisfactory and could hence be used for future prediction purposes.

The final form of the forecasting model developed through step up regression technique was

$$Y = 40.7998 + 15.040391\ Z_{42} - 1.9630814\ Z'_{42} + 0.7073733\ Z'_{43}$$

3. $S2M3.V_2$

This forecasting model belonged to the model three square model as developed in Chapter III.

Z_{21}, Z_{21}', $Q_{(13)1}$ and $Q_{(24)1}$ were the four predictor variable included in the final crop forecasting model, from the nine preliminary selected variables. Table . 12 illustrates that all the four regression coefficients were statisticcally significant at 5% level of the significance and the R^2 value helped to conclude that the adequacy of fit of a linear regression model to the given set of data on this four predictor variables was satisfactory and could be used for predicting yield in advance of harvest.

The final form of the forecasting model developed through step up regression technique was

$$Y = 0.0289 - 0.0310721 Z_{21} + 0.0000602 Z_{21}' - 0.0001354 Q_{(13)1} + 0.0277012 Q_{(24)1}$$

4. $S2M5.V_2$

This forecasting model belonged to the model five category developed in Chapter III.

The five predictor variables included in the final crop forecasting model, from the nine preliminary selected variables were Z_{33}, Z_{43}, Z_{43}, $Q_{(13)2}$ and $Q_{(14)2}$. Table. 13 illustrates the estimated regression coefficients of these predictor variables along with their standard errors and computed t value. The R^2 value showed that 90.71% of the total variance from the mean in yield response was accounted for by the predictor variables in the fitted forecasting model $S2M5.V_2$. The adequacy and fit of the forecasting model was highly satisfactory, but for the purpose of future use of this forecasting model in predicting the yield in advance of harvest, we should examine other criteria measures corresponding to this model.

The final form of the forecasting model developed through step up regression technique was

$$
\begin{aligned}
Y = {} & 20.4684 + 0.0355348\, Z_{33} - 10.350403\, Z_{43} \\
& + 79.654173\, Z_{43}' - 0.2093713\, Q_{(13)2} \\
& - 4.7068076\, Q_{(14)2}
\end{aligned}
$$

c. Season III

1. $S3M1.V_2$

This forecasting model belonged to the model one square model as developed in Chapter III.

Z_{23}', $Q_{(12)1}$ and $Q_{(13)2}$ and $Q_{(23)2}$ were the four predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these predictor variables with their standard error and computed t value were presented in Table. 14. Out of the four regression coefficient, coefficients of variables Z_{23}' and $Q_{(13)2}$ were found to be statistically significant at 5% level of significance. From the R^2, 84.64% of the total variance from the mean in yield response could be accounted for by the predictor variables in the fitted forecasting model S3M1.V_2. The adequacy and fit of the forecasting model was highly satisfactory, but for the purpose of future use of this forecasting model in predicting the yield in advance of harvest, we should examine other criteria measures corresponding to this model.

The final form of the forecasting model developed through step up regression technique was

$$Y = 25.4733 + 0.001938\, Z_{23}{}' - 0.0071244\, Q_{(12)1}$$
$$- 0.0000055\, Q_{(13)2} - 0.0000505\, Q_{(23)2}$$

2. S3M3.V_2

This forecasting model belonged to the model three square model as developed in Chapter III.

Z_{22} and $Q_{(13)1}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these predictor variables along with their standard error and computed t value were presented in Table 15. The coefficient of the variables Z_{22} was only found to be significant at 5% level of significance and so to decide the future use of this forecasting model in predicting the yield in advance of harvest, we should examine other criteria measures corresponding to this model.

The final form of the forecasting model developed through step up regression technique was

$$Y = 6.7151 + 0.4627584\, Z_{22} - 0.0000718\, Q_{(13)1}$$

3. $S3M4.V_2$

This forecasting model belonged to the model four square root model as developed in Chapter III.

$Q_{(13)2}$ and Z_{33} were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these predictor variables along with their standard error and computed t value were presented in Table . 16. The coefficient of the variable $Q_{(13)2}$ was found to be statistically significant at 5% level of significance. With an R^2 value of 0.6990 the adequacy and fit of the forecasting model was satisfactory, but for the purpose of future use of this forecasting model in predicting the yield in advance of harvest, we should examine other criteria measures corresponding to this model.

The final form of the forecasting model developed through step up regression technique was

$$Y = 13.4367 + 0.0366685\, Z_{33} - 0.016263\, Q_{(13)2}$$

4. $S3M5.V_2$

This forecasting model belonged to the model five square root model as developed in Chapter III.

Z_{33} and $Q_{(13)2}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these predictor variables along with their standard error and computed t value were presented in Table 17. Out of the pair, only the coefficient of the variable $Q_{(13)2}$ was found to be statistically significant at 5% level of significance. With an R^2 value it was concluded that though the adequacy and fit of the forecasting model was satisfactory, but for the purpose of future use of this forecasting model in predicting the yield in advance of harvest, we should examine other criteria measures corresponding to this model.

The final form of the forecasting model developed through step up regression technique was

$$Y = 13.4367 + 0.0366722\ Z_{33} - 0.2276988\ Q_{(13)2}$$

d. Season IV

1. $S4M1.V_2$

This forecasting model belonged to the model one square root model as developed in Chapter III.

Z'_{41} is the only predictor variable included in the final crop forecasting model from the nine preliminary selected variables. The estimated regression coefficients of these predictor variables along with its standard error and computed t value were presented in Table. 18. The coefficient of the variable was found to be significant at

5% level of significance. But the R^2 value did not comprehend the use of this model for the purpose of prediction of yield in advance to harvest, until other criteria measures corresponding to this model were examined.

The final form of the forecasting model developed through step up regression technique was

$$Y = 5.9893 + 0.0085848\ Z_{41}'$$

2. $S4M3.V_2$

This forecasting model belonged to the model three square model developed in Chapter III.

From the nine preliminary selected variables: Z_{12}, Z_{12}' and $Q_{(34)0}$ were the three predictor variables included in the final crop forecasting model. Table. 19 illustrates the regression coefficients along with standard errors and computed t value of these three predictor variables. The coefficients of all the three variables were found to be statistically significant and with an R^2 value of 0.9119. 91.19% of the total variance from the mean in yield response could be accounted for by the predictor variables in the crop forecasting model $S4M3.V_2$. The adequacy and fit of the forecasting model was highly satisfactory and consequently the crop forecasting model $S4M3.V_2$ could be used for future yield prediction purposes.

The final form of the forecasting model developed through step up regression technique was

$$Y = 62.0147 + 16.0107\, Z_{12} - 0.2450205\, Z_{12}' + 0.0452517\, Q_{(34)0}$$

3. $S4M6.V_2$

This forecasting model belonged to the model six square root model developed in Chapter III.

From the nine preliminary selected variables eight variables namely Z_{12}, Z_{12}', $Q_{(13)}$, $Q_{(23)1}$, $Q_{(24)1}$, $Q_{(34)0}$, $Q_{(34)1}$, $Q_{(34)2}$ were included in the final forecasting model. Table . 20 illustrates the regression coefficients along with standard errors and computed t value of all the eight predictor variables. From the R^2 value it could be infered that 99.95% of total variance from the mean in yield response could be accounted for by the predictor variables in the crop forecasting model $S4M6.V_2$. But though the adequacy and fit of the forecasting model was satisfactory to comprehend the use of this model for yield prediction purpose in advance in harvest, we should examine other criteria measures corresponding to this model to arrive at a decision.

The final form of the forecasting model developed through step up regression technique was

$$Y = 5.1752 - 0.0823426\, Z_{12} - 0.0131201\, Z_{12}' + 0.0087789\, Q_{(13)1} + 0.0106178\, Q_{(23)1} + 0.0968339\, Q_{(24)1} - 3.983784\, Q_{(34)0} + 5.8313598\, Q_{(34)1} - 1.8281934\, Q_{(34)2}$$

Table. 7 Step-up regression analysis for the crop forecasting model $S1M3.V_2$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Z_{(22)}$	a_{22}	0.5438892	0.2346620	2.3178*

$S = 10$ $R^2 = 0.4017$ $Ra^2 = 0.3270$

$A_0 = 8.7944$ $t_8 = 2.306$

Table. 8 Step-up regression analysis for the crop forecasting model $S1M4.V_2$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	1.497314	0.458094	3.2686*
$Q_{(13)0}$	$g_{(13)0}$	-0.427498	0.1765203	-2.4218
$Q_{(23)0}$	$g_{(23)0}$	-0.0294396	0.0189184	-1.5559
$Q_{(13)1}$	$g_{(13)1}$	0.8602794	0.6169292	1.3945
$Q_{(23)1}$	$g_{(23)1}$	-1.1534425	0.7747126	-1.4889
$Q_{(24)1}$	$g_{(24)1}$	0.0168138	0.0159286	1.0556

$S = 10$ $R^2 = 0.8906$ $Ra^2 = 0.6719$

$A_0 = -0.1325$ $t_3 = 3.182$

Table. 9 Step-up regression analysis for the crop forecasting model $S1M5.V_2$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	1.3181097	0.3278324	4.0207*
$Q_{(23)1}$	$g_{(23)1}$	-3.036694	0.7714304	-3.9364*
$Q_{(34)1}$	$g_{(34)1}$	4.3626923	1.1151817	3.7877*

$S = 10$ $R^2 = 0.8305$ $Ra^2 = 0.7457$

$A_0 = 0.7318$ $t_6 = 2.447$

Table. 10 Step-up regression analysis for the crop forecasting model $S2M1.V_2$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{43}	a_{43}	0.6058526	0.1527779	3.9656*
Z_{42}	a_{42}	0.9844870	0.4611127	2.1350
Z'_{42}	b_{42}	-0.199961	0.0573992	-3.4837*

$S = 10$ $R^2 = 0.8157$ $Ra^2 = 0.7236$

$A_0 = 38.9794$ $t_6 = 2.447$

Table. 11 Step-up regression analysis for the crop forecasting model $S2M2.V_2$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{43}	b_{43}	0.7073733	0.1842502	3.8392*
Z'_{42}	b_{42}	-1.963814	0.522388	-3.7579*
Z_{42}	a_{42}	15.040391	4.2756538	3.5177*

$S = 10$ $R^2 = 0.8077$ $Ra^2 = 0.7116$

$A_0 = 40.7998$ $t_6 = 2.447$

Table. 12 Step-up regression analysis for the crop forecasting model $S2M3.V_2$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{21}	b_{21}	0.0000602	0.0000159	3.7774*
Z_{21}	a_{21}	-0.0310721	0.0121606	-2.5551*
$Q_{(13)1}$	$g_{(13)1}$	-0.0001354	0.0000401	-3.3791*
$Q_{(24)1}$	$g_{(24)1}$	0.0277012	0.009336	2.9671*

$S = 10$ $R^2 = 0.8856$ $Ra^2 = 0.7426$

$A_0 = 0.0289$ $t_{5\%,5} = 2.571$

Table. 13 Step-up regression analysis for the crop forecasting model S2M5.V_2

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)2}$	$g_{(13)2}$	-0.2093713	0.0639258	-3.2752*
Z'_{43}	b_{43}	79.654173	33.25459	2.3953
Z_{43}	a_{43}	-10.350403	5.3444209	-1.9367
$Q_{(14)2}$	$g_{(14)2}$	-4.7068076	2.8224432	-1.6676
Z_{33}	a_{33}	0.0355348	0.0136606	2.6013

S = 10 R^2 = 0.9899 Ra^2 = 0.9546

A_0 = 20.4684 $t_{5\%,2}$ = 4.303

Table. 14 Step-up regression analysis for the crop forecasting model S3M1.V_2

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)2}$	$g_{(13)2}$	-0.0000055	0.0000018	-3.1127*
Z'_{23}	b_{23}	0.001938	0.0012724	1.5231
$Q_{(23)2}$	$g_{(23)2}$	0.0000505	0.0000139	3.6350*
$Q_{(12)1}$	$g_{(12)1}$	0.0071244	0.0035517	2.0059

S = 10 R^2 = 0.8464 Ra^2 = 0.7236

A_0 = 25.4733 t_5 = 2.571

Table. 15 Step-up regression analysis for the crop forecasting model S3M3.V

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{22}	a_{22}	0.4627584	0.1940170	2.3851*
$Q_{(13)1}$	$g_{(13)1}$	-0.0000718	0.0000324	-2.2154

$S = 10$ $R^2 = 0.6541$ $Ra^2 = 0.5552$

$A_0 = 6.7151$ $t_7 = 2.365$

Table. 16 Step-up regression analysis for the crop forecasting model S3M4.V

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)2}$	$g_{(13)2}$	-0.0162630	0.0057086	-2.8488*
Z_{33}	a_{33}	0.0366685	0.0175509	2.0893

$S = 10$ $R^2 = 0.6990$ $Ra^2 = 0.6130$

$A_0 = 13.4367$ $t_7 = 2.365$

Table. 17 Step-up regression analysis for the crop forecasting model S3M5.V^2

VARIABLE SELECTED	REGRESSION COEFF	REGRESSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)2}$	$g_{(13)2}$	-0.2276988	0.0799192	-2.8491*
Z_{33}	a_{33}	0.0366722	0.0175505	2.0895

S = 10 $\quad R^2 = 0.6990 \quad Ra^2 = 0.6130$

$A_0 = 13.4367 \quad t_7 = 2.365$

Table. 18 Step-up regression analysis for the crop forecasting model S4M1.V^2

VARIABLE SELECTED	REGRESSION COEFF	REGRESSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{41}	b_{41}	0.0085848	0.0031450	2.7297*

S = 10 $\quad R^2 = 0.4822 \quad Ra^2 = 0.4175$

$A_0 = 5.9893 \quad t_7 = 2.306$

Table. 19 Step-up regression analysis for the crop forecasting model $S4M3.V_2$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	0.0452517	0.1099657	4.1151*
Z_{12}	a_{12}	16.0107	5.1176805	3.1285*
Z'_{12}	b_{12}	-0.2450205	0.0799308	-3.0654*

$S = 10$ $R^2 = 0.9119$ $Ra^2 = 0.8678$

$A_0 = 62.0147$ $t_6 = 2.447$

Table. 20 Step-up regression analysis for the crop forecasting model $S4M6.V_2$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$g_{(34)2}$	-1.8281934	1.106666	-1.6520
$Q_{(34)1}$	$g_{(34)1}$	5.8313598	1.9859299	2.9363
$Q_{(24)1}$	$g_{(24)1}$	0.0968339	0.0171477	5.6471
$Q_{(34)0}$	$g_{(34)0}$	-3.983784	0.8889646	-4.4814
Z'_{12}	b_{12}	-0.0131201	0.0084951	-1.5444
Z_{12}	a_{12}	-0.0823426	0.0887382	-9.2793
$Q_{(13)1}$	$g_{(13)1}$	0.0087789	0.0028487	3.0817
$Q_{(23)1}$	$g_{(23)1}$	0.0106178	0.0053754	1.9753

$S = 10$ $R^2 = 0.9995$ $Ra^2 = 0.9958$

$A_0 = 5.1752$ $t_1 = 12.706$

4.2.3 Statistical analysis of the chosen forecasting models of Variety 3.

A total of ten models were selected under the variety three. namely one model from Season I, three models from Season III and six models from Season IV.

a. Season I

1. $S1M4.V_3$

$Q_{(34)0}$ and $Z_{(41)}$ are the two predictor variables included in the final forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of this predictor variables along with their standard error and computed t value were illustrated in Table . 21. It was noticed that the coefficients of both the variables were statistically significant at 5% level of significance from the R^2 value it could be concluded that the adequacy and fit of the forecasting model was satisfactory and hence this model could be used for the prediction of yield prior to harvest.

The final form of the forecasting model developed through step up regression technique was

$$Y = -3.1358 + 0.2518198\ Z_{41} + 0.2006578\ Q_{(34)0}$$

1. $S3M2.V_3$

This forecasting model belonged to the model two square model category developed in chapter III

Z_{41}', Z_{42}', Z'_{43} and $Q_{(14)0}$ were the four predictor variables incorporated into the final crop forecasting model from the nine preliminary selected variables. The estimated regression coeficients of these variables alone with their standard error and computed t value were presented in Table . 22. Out of the four regression coefficients, only the coefficients of variables Z_{41}' and Z_{43}' were found to be significant. The R^2 the value signified that the adequacy and fit of the model was satisfactory and hence could be used for the prediction of yield in advance of harvest.

The final crop forecasting model developed through step up regression was

$$Y = 23.0813 + 35.8656\ Z41' - 25.612316\ Z42'$$

$$+ 4.437334\ Z_{43}' - 0.0473512\ Q_{(14)0}$$

2. $S3M3.V_3$

This forecasting model belonged to the model three (square model) category developed in Chapter III

Z_{41}' and $Q_{(24)1}$ were the two predictor variables included in the crop forecasting model from the nine preliminary selected variable. The estimated regression coefficient of these variables along with their standard error and computed t values were illustratred in Table. 23 The coefficients of the variable Z_{41} was found to be significant at 5% level of significance. Taking into consideration the R^2 value it was concluded that inspite of satisfactory adequacy and fit of the forecasting model, its use in the field of prediction of yield prior to harvest could be adjudged only on examining its performance with other criteria measures.

$$Y = 0.4970 + 0.0952982\ Z_{41}' - 0.0027565\ Q_{(24)1}$$

was the final forecasting model developed.

3. $S3M6.V_3$

This forecasting model belonged to the model six category (square root model) as developed in Chapter III.

Z_{12}' was the only variable included in the crop forecasting model from the nine preliminary selected variable. Table. 24 illustrated the estimated regression coefficient of this variable with its standard error and computed t value. Though the coefficient of the variable was found to be statistically significant at 5% level of significance, the use of this model for the purpose of prediction of yield in advance of harvest could not be consumed unless other criteria measures are examined.

The final crop forecasting model developed through step up regression was

$$Y = 24.1815 - 2.0120804\ Z_{12}'$$

c. Season 1V

1. $S4M1.V_3$

This crop forecasting model belonged to the model one (square model) category as developed in Chapter III.

$Q_{(14)0}$ was the only predictor variable included in the final crop forecasting from the nine preliminary selected variables. The estimated regression coefficient of this variable with its standard error and computed t value was illustrated in Table. 25. The coefficient of the variable $Q_{(14)0}$ was found to be statiscally significant, but the use of this model for prediction purpose could be adjudged only on examining its performance with other criteria measures.

The final form of the crop forecasting model developed through step up regression was

$$Y = 5.9893 + 0.0085848\ Q_{(14)0}$$

2. $S4M2.V_3$

This forecasting model belonged to the model two (square model) category as developed in Chapter III.

$Q_{(14)0}$ was the only predictor variable included in the final forecasting model from the nine preliminary selected variable. The estimated regression coefficient of this variable with its standard error and computed t value were illustrated in Table. 26. The coefficient of the variable $Q_{(14)0}$ was found to be significant at 5% level of significance. From the R^2 value it was concluded that to utilize this model for prediction purposes, its performance with other criteria measures should also be examined.

$$Y = 6.6819 + 0.544557\ Q_{(14)0}$$

was the final crop forecasting model developed through step up regression.

3. $S4M3.V_3$

This forecasting model belonged to the model three (square model) category as developed in Chapter III.

Six predictor variables namely Z_{12}, Z_{41}, Z_{42}', $Q_{(13)1}$, $Q_{(34)1}$ and $Q_{(34)2}$ were included in the final crop forecasting model, from the nine preliminary selected variables. Table. 27 illustrated the estimated regression coefficient of these variable along with their standard error and computed t value. It was noted that all the regression coefficient except those of variables Z_{41} and $Q_{(13)}$ were found to be statistically significant. An R^2 value of 0.9849 signified that 98.49% of the total variance from the mean in yield response was accounted for by the predictor variables fitted in the final forecasting model. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be used for predicting the yield in advance of harvest.

The final crop forecasting model developed through step up regressions technique was

$$Y = 7.9017 + 1.2814376\ Z_{12} - 1.9056612\ Z_{41}$$
$$+ 0.3205444\ Z'_{42} + 0.0178271\ Q_{(13)1}$$
$$+ 0.6543014\ Q(34)1 - 0.6187844\ Q(34)2.$$

4. $S4M4.V_3$

This forecasting model belonged to the model four (square root model) categony as developed in Chapter III.

$Q_{(34)1}$ and $Q_{(14)0}$ were the two predictor variables included in the forecasting model from the nine preliminary selected variables. The estimated regression coefficient of these variables along with their standard error and computed t value were presented in Table. 28. From the two regression coefficients only the coefficient of the variable $Q_{(34)1}$ was found to be significant at 5% level of significance. Based on the R^2 value, 83.82% of the total variance from the mean in yield response was accounted for by the predictor variables fitted in the forecasting model. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be used for predicting the yield in advance of harvest.

The final crop forecasting model developed through step up regression technique was

$$Y = 14.3138 + 0.0867845\ Q_{(14)0} + 0.0447234\ Q_{(34)1}$$

5. $S4M5.V_3$

This forecasting model belonged to the model five (square root model) category as developed in chapter III

$Q_{(14)0}$ and $Q_{(34)1}$ were the predictor variables included in the final crop forecasting from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 29. Even if only the coefficient of the variable $Q_{(34)1}$ was found to be significant at 5% level of significance, these two variables accounted for 83.82% of the total variance from the mean of the yield response in the crop forecasting model. The adequacy and fit of the model was satisfactory and hence could be used for the purpose of predicting the yield prior to harvest.

$$Y = 4.3140 + 0.5207259\ Q_{(14)0}$$

$$+ 0.9391837\ Q_{(34)1}$$

was the final crop forecasting model developed through step up regression techniques.

6. $S4M6.V_3$

This crop forecasting model belonged to the model six (square root model) category as developed in Chapter III

Z_{12}', $Q_{(23)0}$, $Q_{(23)1}$ and $Q_{(34)0}$ were the predictor variables included in the crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these predictor variables along with their standard error and computed t values were illustrated in Table . 30 except for the regression coefficient of the variable Z_{12}', the coefficients of the other three variables were found to be statistically significant at 5% level of significance. From the R^2 value it could be concluded that 97.55% of the total variance from the mean of yield response was accounted for by the predictor variables in the crop forecasting model. The adequacy and fit of the model was satisfactory and hence could be used for the purpose of predicting the yield in advance of the harvest.

The final crop forecasting model developed through step up regression was

$$Y = 23.6673 + 2.2881135\ Z_{12}' + 0.3927293\ Q_{(23)0} - 0.1559021\ Q_{(23)1} + 1.3805265\ Q_{(34)0}$$

Table. 21 Step-up regression analysis for the crop forecasting model $S1M4.V_3$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	0.2006578	0.0688993	2.9123*
Z_{41}	a_{41}	0.2518198	0.0996393	2.5273*

S = 10 R^2 = 0.7157 Ra^2 = 0.6345

A_0 = -3.1358 t_7 = 2.365

Table. 22 Step-up regression analysis for the crop forecasting model $S3M2.V_3$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{42}	b_{42}	-25.612316	10.773758	-2.3773
Z'_{41}	b_{41}	35.8656	12.455432	2.8795*
Z'_{43}	b_{43}	4.437334	1.4612864	3.0366*
$Q_{(14)0}$	$g_{(14)0}$	-0.0473512	0.0196264	-2.4126

S = 10 R^2 = 0.7815 Ra^2 = 0.6067

A_0 = 23.0813 t_5 = 2.571

Table. 23 Step-up regression analysis for the crop forecasting model S3M3.V_3

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(24)1}$	$g_{(24)1}$	-0.0027565	0.0013400	-2.0571
Z'_{41}	b_{41}	0.0952982	0.0311886	3.0555*

S = 10 R^2 = 0.6348 Ra^2 = 0.5305

A_0 = 0.4970 t_7 = 2.365

Table. 24 Step-up regression analysis for the crop forecasting model S3M6.V_3

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{12}	b_{12}	-2.0120804	0.8064828	-2.4949*

S = 10 R^2 = 0.4376 Ra^2 = 0.3673

A_0 = 24.1815 t_8 = 2.306

Table. 25 Step up regression analysis for the crop forecasting model S4M1.V_3

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(14)0}$	$g_{(14)0}$	0.0085848	0.0031450	2.7297*

S = 10 R^2 = 0.4822 Ra^2 = 0.4175

A_0 = 5.9893 t_8 = 2.306

Table. 26 Step-up regression analysis for the crop forecasting model $S4M2.V_3$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(14)0}$	$g_{(14)0}$	0.544557	0.0189139	2.8791*

$S = 10$ $R^2 = 0.5089$ $Ra^2 = 0.4475$

$A_0 = 6.6819$ $t_8 = 2.306$

Table. 27 Step-up regression analysis for the crop forecasting model $S4M3.V_3$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.6543014	0.1611963	4.0590*
$Q_{(34)2}$	$g_{(34)2}$	-0.6187844	0.1866460	-3.3153*
Z_{12}	a_{12}	1.2814376	0.3808811	3.3644*
Z_{41}	a_{41}	-1.9056612	1.3909006	-1.3701
Z'_{42}	b_{42}	0.3205444	0.073009	4.3901*
$Q_{(13)1}$	$g_{(13)1}$	0.0178271	0.0068577	2.5996

$S = 10$ $R^2 = 0.9849$ $Ra^2 = 0.9548$

$A_0 = 7.9017$ $t_3 = 2.182$

Table. 28 Step-up regression analysis for the crop forecasting model $S4M4.V_3$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.0447234	0.0116174	3.8497*
$Q_{(14)0}$	$g_{(14)0}$	0.0867845	0.0478455	1.8138

$S = 10$ $R^2 = 0.8382$ $Ra^2 = 0.7920$

$A_0 = 14.3138$ $t_7 = 2.365$

Table. 29 Step-up regression analysis for the crop forecasting model $S4M5.V_3$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.9391837	0.2439633	3.8497*
$Q_{(14)0}$	$g_{(14)0}$	0.5207259	0.2870729	1.8139

$S = 10$ $R^2 = 0.8382$ $Ra^2 = 0.7920$

$A_0 = 4.3140$ $t_6 = 2.365$

Table. 30 Step-up regression analysis for the crop forecasting model $S4M6.V_3$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	1.3805265	0.1782720	7.7439*
$Q_{(23)1}$	$g_{(23)1}$	-0.1559021	0.0537739	-2.8992*
$Q_{(23)0}$	$g_{(23)0}$	0.3927293	0.0934142	4.2042*
Z'_{12}	b_{12}	2.2881135	1.4162392	1.6158

$S = 10$ $R^2 = 0.9755$ $Ra^2 = 0.9559$

$A_0 = 23.6673$ $t_5 = 2.571$

4.2.4 Statistical analysis of the chosen forecasting models of Variety 4.

A total of nine models were selected under the Variety 4, namely two models from Season I, four models from Season II, two models from Season III and one from Season IV.

a. Season I

1. $S1M4.V_4$

Z_{41}, Z_{43}, Z_{31}', $Q_{(13)0}$ and $Q_{(24)1}$ were the five predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 31. It was noted that the coefficients of these variables were all found to be statistically significant. From the R^2 value it is evident that 94.96% of the total variance from the mean in yield response was accounted for by the predictor variables fitted in the final crop forecasting model. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be used for the purpose of predicting the yield in advance of harvest.

The final crop forecasting model developed through step up regression technique was

$$Y = 39.0301 - 3.8433322\, Z_{41} + 1.3331079\, Z_{43} - 55.66081\, Z_{31}' + 9.8535442\, Q_{(13)0} - 1.2378739\, Q_{(24)1}$$

2. S1M5.V

This forecasting model belonged to the model five (square root model) category as developed in Chapter III.

Six predictor variables Z_{31}', Z_{41}, $Q_{(13)0}$, $Q_{(13)1}$, $Q_{(23)1}$ and $Q_{(34)1}$ were included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 32. Of the six variables, the coefficients of only three variables i.e. Z_{41}, $Q_{(13)1}$ and $Q_{(23)1}$ were found to be statistically significant at 5% level of significance. 97.59% of the total variance from the mean in yield response was accounted for by the predictor variables fitted in the final forecasting model. The adequacy and fit of this forecasting model was found to be satisfactory and hence this model coulb be used for the purpose of predicting the yield prior to harvest.

The final form of the crop forecasting model obtained through the step up regression technique was

$$Y = -1.3590 + 0.3874032 Z_{41} - 56.540889 Z_{31}' + 11.337531 Q_{(13)0} + 9.5409059 Q_{(13)1} + 1.9382851 Q_{(34)1} - 14.092514 Q_{(23)1}$$

b. Season II

1. S2M1.V

$_4$

This forecasting model belonged to the model one (square model) category as developed in Chapter III.

The five predictor variables included in the final crop forecasting model from the nine preliminary selected variables were Z_{42}, Z_{42}', Z_{43}', $Q_{(14)2}$ and $Q_{(24)1}$. Table . 33 illustrated the estimated regression coefficients of these variables along with their standard error and computed t values. The coefficients of the variables Z_{42}', $Q_{(14)2}$ and $Q_{(24)1}$ were found to be significant at 5% level of significance. With an R^2 value of 0.9118, 91.18% of the total variance from the mean in yield response was accounted for by the predictor variables in the forecasting model. The adequacy and fit of the model was satisfactory and hence this model could be used for the successful prediction of yield prior to harvest.

$$Y = 48.48180 - 1.7075216\ Z_{42} - 0.3044262\ Z_{42}' - 0.0030745\ Z_{43}' + 0.048469\ Q_{(14)2} + 0.0647926\ Q_{(24)1}$$

was the final crop forecasting model developed through step up regression technique.

2. S2M3.V

$_4$

This forecasting model belonged to the model three (square model) category as developed in Chapter III.

From the nine preliminary selected variables, Z_{31}, Z_{33}, $Q_{(12)1}$ and $Q_{(14)1}$ were the four predictor variables included in the final crop forecasting model. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 34. The coefficients of the variables Z_{33} and $Q_{(12)1}$ were found to be significant at 5% level of significance. From the R^2 value it could be concluded that 95.54% of the total variance from the mean in yield response could be accounted for by the predictor variables fitted in the final crop forecasting model. The adequacy and fit of the model was highly satisfactory and hance this model could be used for the prediction of yield prior to harvest.

The final form of the crop forecasting model developed through step up regression was

$$Y = 42.4064 + 0.0275773\, Z_{31} - 0.04321551\, Z_{33}$$

$$- 0.0519984\, Q_{(12)1} - 0.0072269\, Q_{(14)1}$$

3. $S2M4.V_4$

This forecasting model belongs to the model four (square root model) category as developed in Chapter III.

Z_{42}, Z_{43}, Z_{42}', Z_{43}' and $Q_{(24)2}$ were the five predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. Table . 35 presented the estimated regression coefficients along with their standard error and computed t values of these predictor variables. All the coefficients except that of the variable $Q_{(24)2}$ were found to be significant at 5% level of significance. 90.53% of the total variance from the mean of yield response was accounted for by these predictor variables fitted in the crop forecasting model. With the adequacy and fit of the model being highly satisfactory, this model could be utilised for the purpose of prediction yield prior to harvest.

The final form of the crop forecasting model obtained through step up regression was

$$Y = -111.7853 + 14.296205 Z_{42} + 4.5715188 Z_{43} + 56.718864 Z_{42}' - 19.350553 Z_{43}' + 0.45969166 Q_{(24)2}$$

4. $32M6.V_4$

This forecasting model belonged to the model six (square model) category as developed in Chapter 3.

Z'_{33} and $Q_{(12)1}$ were the only two variables included in the final crop forecasting model from the nine preliminary selected variable. The estimated regression coefficients of these variables along with standard errors and computed t values were presented in Table. 36. The coefficients of both variables were found to be significant at 5% level of significance 90.34% of the total variance from the mean of yield response was accounted for by the predictor variable in the forecasting model. The adequacy and fit of the model could be used for the purpose of predicting yield prior to harvest

$$Y = 34.4171 + 0.2672568\ Z'_{33} - 0.0418013\ Q_{(12)1}$$

was the final crop forecasting model develpoed through step up regression.

c. Season III

1. S3M1.V_4

This forecasting model belongs to the model one (square model) category as developed in Chapter III.

The predictor variables included in the final crop forecasting model, from the nine preliminary selected variables were Z'_{41}, Z'_{42}, Z'_{43}, $Q_{(14)0}$ and $Q_{(14)1}$. The estimated regression coefficients of these variables with their standard error and computed t value were presented in Table. 37. Though 84.78% of the total variance from the mean of yield response could be accounted for by these predictor variables in the forecasting model, the use of this model for the purpose of predicting yield prior to harvest could be decided only after further investigation of its performance with other criteria measures.

The final form of the crop forecasting model through step up regression technique was

$$Y = 0.2878 + 0.3033882\ Z'_{41}\ \ 0.4471587\ Z'_{42} + 0.1246885\ Z'_{43} + 0.0164368\ Q_{(14)0} - 0.0065406\ Q_{(14)1}$$

2. $S3M4.V_4$

This forecasting model belonged to the model four (square root model) as developed in Chapter III .

The four predictor variables included in the final crop forecasting model from the nine preliminary selected variables were Z_{33} , Z_{43} , Z'_{33} and $Q_{(13)2}$. The estimated regression coefficients of these predictor variables along with their standard error and computed t value were presented in Table . 38. The coefficients of all the variables except that of the variable Z_{33} were found to be statistically significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory and hence this model could be used for the purpose of predicting yield prior to harvest.

$$Y = 3.1749 + 0.0286044\ Z_{33} + 1.0590599\ Z_{44} - 1.6852889\ Z'_{33} + 0.2785813\ Q_{(13)2}$$

d. Season IV

1. $S4M1.V_4$

This forecasting model belonged to the model one (square model) as developed in chapter III.

Z_{41} and $Q_{(14)0}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficient of these variables along with the standard error and computed t values were presented in Table. 39.

Both the coefficients were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory, but the use of this model for the purpose of predicting the yield could be judged only after examining its performance with other criteria measures.

The final form of the crop forecasting model developed through step up regression was

$$Y = 3.4478 - 0.0099233\, Z_{41} + 0.0059346\, Q_{(14)0}$$

Table. 31 Step-up regression analysis for the crop forecasting model S1M4.V_4

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{12}	b_{12}	-55.66081	11.229543	-4.9566*
$Q_{(13)0}$	$g_{(13)0}$	9.8535442	1.9755207	4.9878*
Z_{43}	a_{43}	1.3331079	0.22315576	5.9739*
Z_{41}	a_{41}	-3.8433322	0.73593134	-5.2224*
$Q_{(24)1}$	$g_{(24)1}$	-1.2378739	0.1932984	-6.4040*

S = 10 R^2 = 0.9496 Ra^2 = 0.8489

A_0 = 39.0301 t_4 = 2.776

Table. 32 Step-up regression analysis for the crop forecasting model S1M5.V_4

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{31}	b_{31}	-56.540889	20.096981	-2.8134
$Q_{(13)0}$	$g_{(13)0}$	11.337531	3.6076052	3.1427
$Q_{(34)1}$	$g_{(34)1}$	1.9382851	1.4367491	1.3491
$Q_{(13)1}$	$g_{(13)1}$	9.5409059	1.6283308	5.8593*
$Q_{(23)1}$	$g_{(23)1}$	-14.092514	2.3868098	-5.9043*
Z_{41}	a_{41}	0.3874032	0.0941872	4.1131*

S = 10 R^2 = 0.9759 Ra^2 = 0.9277

A_0 = -1.3590 t_3 = 3.182

Table. 33 Step-up regression analysis for the crop forecasting model S2M1.V_4

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(14)2}$	$g_{(14)2}$	0.048469	0.0089836	5.3952*
Z'_{43}	b_{43}	-0.0030745	0.0016834	-1.8263
Z_{42}	a_{42}	-1.7075216	0.779470	-2.1906
Z'_{42}	b_{42}	-0.3044262	0.0625578	-4.8663*
$Q_{(24)1}$	$g_{(24)1}$	0.0647926	0.0206273	3.1411*

$S = 10$ $R^2 = 0.9118$ $Ra^2 = 0.8016$

$A_0 = 48.8180$ $t_4 = 2.776$

Table. 34 Step-up regression analysis for the crop forecasting model S2M3.V_4

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{33}	a_{33}	-0.04321551	0.0123738	-3.4925*
$Q_{(12)1}$	$g_{(12)1}$	0.0519984	0.0067038	7.7566*
Z_{31}	a_{31}	0.0275773	0.0121558	2.2686
$Q_{(14)1}$	$g_{(14)1}$	-0.0072269	0.0055164	-1.3101

$S = 10$ $R^2 = 0.9554$ $Ra^2 = 0.9198$

$A_0 = 42.4064$ $t_{5\%,5} = 2.571$

Table. 35 Step-up regression analysis for the crop forecasting model S2M4.V_4

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{43}	b_{43}	-19.350553	5.9213938	-3.2679*
Z_{43}	a_{43}	4.5715188	1.2490155	3.6601*
$Q_{(24)2}$	$g_{(24)2}$	0.45969166	0.1782101	2.5795
Z'_{42}	b_{42}	56.718864	12.50295	4.5364*
Z_{42}	a_{42}	14.296205	2.954707	-4.8385*

S = 10 R^2 = 0.9053 Ra^2 = 0.7870

A_0 = -111.7853 t_4 = 2.776

Table. 36 Step-up regression analysis for the crop forecasting model S2M6.V_4

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{33}	b_{33}	0.2672568	0.0413924	-6.4567*
$Q_{(12)1}$	$g_{(12)1}$	-0.0418013	0.0067981	-6.1489*

S = 10 R^2 = 0.9034 Ra^2 = 0.8785

A_0 = 34.4171 t_7 = 2.365

Table. 37 Step-up regression analysis for the crop forecasting model S3M1.V_4

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{43}	b_{43}	0.1246885	0.0532895	2.3398
Z'_{42}	b_{42}	-0.4471587	0.2076176	-2.1538
$Q_{(14)1}$	$g_{(14)1}$	-0.0065406	0.0018039	-3.6257*
Z'_{41}	b_{41}	0.3033882	0.1648582	1.8403
$Q_{(14)0}$	$g_{(14)0}$	0.0164368	0.0105605	1.5564

$S = 10$ $R^2 = 0.8478$ $Ra^2 = 0.7261$

$A_0 = 0.2878$ $t_6 = 2.447$

Table. 38 Step-up regression analysis for the crop forecasting model S3M4.V_4

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)2}$	$g_{(13)2}$	0.2785813	0.0787802	3.5362*
Z'_{33}	b_{33}	-1.6852889	0.4645893	-3.6275*
Z_{43}	a_{43}	1.0590599	0.2618109	4.0451*
Z_{33}	a_{33}	0.0286044	0.0168841	1.6942

$S = 10$ $R^2 = 0.8315$ $Ra^2 = 0.7541$

$A_0 = 3.1749$ $t_5 = 2.571$

Table. 39 Step-up regression analysis for the crop forecasting model $S4M1.V_4$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(14)0}$	$g_{(14)0}$	0.0059346	0.0014780	4.0154*
Z_{41}	a_{41}	-0.0099233	0.0026941	-3.6833*

$S = 10$ $R^2 = 0.7495$ $Ra^2 = 0.6779$

$A_0 = 3.4478$ $t_6 = 2.365$

4.2.5 Statistical analysis of the chosen forecasting models under Variety 5

A total of six models i.e. one from Season I, one form Season II, one from Season III and three from Season IV were selected under Variety 5.

a. Season I

1. $S1M6.V_5$

This forecasting model belonged to the model six (square root model) as developed in Chapter III

The four predictor variables included in the final crop forecasting model from the nine preliminary selected variables were Z_{22}, Z_{12}', Z_{22}' and $Q_{(12)1}$. The estimated regression coefficients of those predictor variables along with their standard errors and computed t values were presented in Table. 40. The coefficients of only two variables, namely $Q_{(12)1}$ and Z_{12}' were found to be statistically significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory but the use of this model for the purpose of prediction of yield prior to harvest should be decided based on its performance with other criteria functions.

The final form of the crop forecasting model developed through step up regression was

$$Y = -751.7054 - 9.1549606\ Z_{22} + 88.454093\ Z_{12}' + 132.49152\ Z_{22}' - 0.2133003\ Q_{(12)1}$$

b. Season II

1. $S2M6.V_5$

This forecasting model belonged to the model six (square root model) category as developed in Chapter III.

Z_{31}' and $Q_{(12)1}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t value were presented in Table. 41. The coefficients of these varibles were found to be significant at 5% level of significance. Though the adequacy and fit of this model was found to be satifactory, the use of this model for future prediction purpose of crop yield in advance of harvest could be confirmed based on the performance of this model with other criteria measures.

The final form of the crop forecasting model developed through step up regression was

$$Y = 39.7022 - 0.55482\ Z_{31}' - 0.0443577\ Q_{(12)1}$$

c. Season III

1. $S3M3.V_5$

This forecasting model belonged to the model three (square model) category as developed in Chapter III.

Z_{22}', $Q_{(23)1}$ and $Q_{(34)1}$ were the three predictor variables included in the final crop forecasting model from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 42. The coefficients of all the three variables were found to be significant at 5% level of significance. 92.17% of the total variance from the mean of the yield response was accounted for by the predictor variables fitted in the forecasting model. The adequacy and fit of this model was found to be highly satisfactory and hence could be used for the purpose of predicting yield in advance of harvest.

The final form of the crop forecasting model developed through step up regression was

$$Y = 1.2982 + 0.012832\, Z'_{22} - 0.0000437\, Q_{(23)1} + 0.0004246\, Q_{(34)1}$$

d. Season IV

1. $34M3.V_5$

This forecasting model belonged to the model three (square model) category as developed in Chapter III.

From the nine preliminary selected variables, four predictor variables Z_{32}, Z'_{12}, $Q_{(12)1}$ and $Q_{(14)1}$ were included in the final crop forecasting model. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 43. The coefficients of all the variables except that of Z_{32} were found to be statistically significant at 5% level of significance. From the R^2 value, it could be concluded that 90% of the total variance from the mean of yield response could be accounted for by the predictor variables fitted in the final crop forecasting model. The adequacy and fit of this model was found to be highly satisfactory and hence could be used for the purpose of predicting yield to harvest.

$$Y = 7.88408 + 0.0941086\ Z_{32} + 0.8080479\ Z_{12}' - 0.2271411\ Q(12)1 - 0.3518853\ Q(14)1$$

was the final crop forecasting model developed through step up regression.

2. $S4M5.V_5$

This forecasting model belonged to the model five (square root model) category as developed in Chapter III.

The four predictor variables included in the final crop forecasting model from the nine preliminary selected variables were Z_{23}, Z_{23}', $Q_{(12)2}$ and $Q_{(23)2}$. The estimated regression coefficients of these variables with their standard error and computed t value were represented in Table . 44. Of the regression coefficients of the four variables only the coefficients of variable Z_{23}' and $Q_{(12)2}$ were found to be significant at 5% level of significance. The adequacy and fit of this model was found to be satisfactory but the use of this model for prediction purposes could be ascertained only after its performance with other criteria functions were studied

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 122.9327 + 0.74635\ Z_{23} - 142.62421\ Z'_{23} + 19.734087\ Q_{(12)2} + 0.4177477\ Q_{(23)2}$$

3. S4M6.V5

This forecasting model belonged to the model six (square root model) as developed in Chapter III.

The only variable which was included in this forecasting model from the nine preliminary selected variables was $Q_{(24)1}$ whose estemated regression coefficients, standard error and computed t values were presented in Table. 45. The coefficient of this variable was found to be sinificant at 5% level of significance. Though the adequacy and fit of the model was satisfactory its use in the field of predicting yield prior to harvest is to be judged on basis of its performance to other criteria measures.

The final form of the forecasting model developed through step up regression was

$$Y = 2.94 + 0.2799615\ Q_{(24)1}$$

Table. 40 Step-up regression analysis of the crop forecasting model $S1M6.V_5$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{22}	b_{22}	132.49152	77.776732	1.7035
Z_{22}	a_{22}	-9.1549606	6.3240866	-1.4476
$Q_{(12)1}$	$g_{(12)1}$	-0.2133003	0.0728762	-2.9269*
Z'_{12}	b_{12}	88.454093	22.184886	3.7871*

$S = 10$ $R^2 = 0.8763$ $Ra^2 = 0.7774$

$A_0 = -751.7054$ $t_5 = 2.571$

Table. 41 Step-up regression analysis of the crop forecasting model $S2M6.V_5$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{31}	b_{31}	-0.554812	0.1570981	-3.5317*
$Q_{(12)1}$	$g_{(12)1}$	-0.0443577	0.0125919	3.5227*

$S = 10$ $R^2 = 0.7484$ $Ra^2 = 0.6765$

$A_0 = 39.7022$ $t7 = 2.365$

Table. 42 Step-up regression analysis of the crop forecasting model $S3M3.V_5$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.0004246	0.0001372	3.0943*
$Q_{(23)1}$	$g_{(23)1}$	-0.0000437	0.0000111	-3.9327*
Z'_{22}	b_{22}	0.0128320	0.0035058	3.6603*

S = 10 $\quad R^2$ = 0.9217 $\quad Ra^2$ = 0.8826

A_0 = 1.2983 $\quad t_6$ = 2.447

Table. 43 Step-up regression analysis of the crop forecasting model $S4M3.V_5$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{32}	a_{32}	0.0941086	0.0493414	1.9073
Z'_{12}	b_{12}	0.8080479	0.1289374	6.2670*
$Q_{(14)1}$	$g_{(14)1}$	-0.3518853	0.0882687	-3.9865*
$Q_{(12)1}$	$g_{(12)1}$	-0.2271411	0.0778507	-2.9176*

S = 10 $\quad R^2$ = 0.9000 $\quad Ra^2$ = 0.8200

A_0 = 7.88408 $\quad t_5$ = 2.571

Table. 44 Step-up regression analysis of the crop forecasting model $S4M5.V_5$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(12)2}$	$g_{(12)2}$	19.734087	6.1500172	3.2088*
Z'_{23}	b_{23}	-142.62421	50.782947	-2.8085*
Z_{23}	a_{23}	0.7463500	0.3703334	2.0153
$Q_{(23)2}$	$g_{(23)2}$	0.4177477	0.2098264	1.9909

$S = 10$ $R^2 = 0.7479$ $Ra^2 = 0.4327$

$A_0 = 122.9327$ $t_5 = 2.571$

Table. 45 Step-up regression analysis of the crop forecasting model $S4M6.V_5$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(24)1}$	$g_{(24)1}$	0.2799615	0.0665737	4.2053*

$S = 10$ $R^2 = 0.6885$ $Ra_2 = 0.6496$

$A_0 = 2.9400$ $t_8 = 2.306$

4.2.6 Statistical analysis of the chosen forecasting model under Variety 6.

A total six models three from Season II, two from Season III and one from Season IV, were selected under Variety 6.

a. Season II

1. $S2M2.V_6$

This forecasting model belonged to the model two (square model) category developed in Chapter III.

Z_{32}' was the only variable included in the final crop forecasting model from the nine preliminary selected variables. The estimated regression coefficient of this variable along with its standard error and computed t value were presented in Table. 46. The coefficient of this variable was found to be significant at 5% level of significance. The ability of this model in the prediction of yield prior to harvest could be decided only after verifying it performance with other criteria measures.

The final form of this crop forecasting model developed through step up regression was

$$Y = 1.4323 + 0.000236\ Z_{32}'$$

2. $S2M3.V_6$

This forecasting model belonged to the category of square models namely model three, as developed in Chapter 3.

In this crop forecasting model $Q_{(34)1}$ is the only variable included from the nine preliminary selected variables. The table. 47 which continued the estimated regression coefficients of the predictor variables along with its standard error and computed t value, whowed that the coefficient of the variable was significant at 5% level of significance. The use of this model for the purpose of predicting yield could be judged only after rating its performance with other criteria measures.

The final form of the crop forecasting model developed through step up regression was

$$Y = 2.1915 + 0.0005994\ Q_{(34)1}$$

3. $S2M4.V_6$

This forecasting model belongs to the category of square root models namely model four, as developed in Chapter 3.

The seven predictor variables included in the final crop forecasting model from the nine preliminary selected variable were Z_{22}, Z_{31}, Z_{43}, Z'_{21}, Z'_{23}, Z'_{43} and $Q_{(14)2}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 48. From the table it was noted that the coefficients of all the variables were found to significant at 5% level of significance 99.36% of the total variance from the mean of yield response was accounted for by the predictor variables fitted in the crop forecasting model. The adequacy and ifit of the model was found to be highly satisfactory. hence this model could be used for the purpose of predicting yield in advance of harvest.

The final form of the crop forecasting model developed through stepup regression technique was

$$Y = 2043.6768 + 14.545209\, Z_{22} + 0.0083411\, Z_{31} - 2.2541117\, Z_{43} - 152.8894\, Z'_{21} - 30.28649\, Z'_{23} + 6.3456912\, Z'_{43} + 0.8100659\, Q_{(14)2}$$

b. Season III

1. S3M2.V_6

This forecasting model belonged to the square model category namely model one, as developed in Chapter III.

Z'_{31} and $Q_{(23)0}$ were the two predictor variables included in the final crop forecasting model from the nine preliminary selected variable. The estimated regression coefficients of these variables with its standard error and computed t values were presented in Table. 49. Both the coefficients were found to be significant at 5% level of significance. The adequacy and fit of this model was found to be satisfactory, but the use of this model for the purpose of predicting yield in advance of harvest can be judged on the basis of its performance with other criteria measures.

The final crop forecasting model developed through step up regression technique was

$$Y = 3.3448 + 0.0000198\, Z'_{31} - 0.0004563\, Q_{(23)0}$$

2. $S3M3.V_6$

This forecasting model belonged to the category of square models namely model three, as developed in Chapter 3.

$Q_{(34)1}$ was the only variable included in the final crop forecasting model from the nine preliminary selected variables. Table . 50 which presented the estimated regression coefficient of the perdictor variable along with its standard error and computed t value, informed the significance of the coefficient at 5% level of significance. The use of this model for prediction purpose could be ascertained only after reviewing its performance with other criteria measures.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 1.6814 + 0.0005637\, Q_{(34)1}$$

c. Season IV

1. $S4M3.V_6$

This forecasting model belonged to model three (square model) category asdeveloped in Chapter III.

$Q_{(23)1}$ and $Q_{(34)2}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these predictor variables along with their standard error and computed t value were presented in Table . 51. Of the two coefficients, only the coefficient of the variable $Q_{(34)2}$ was found to be significant at 5% level of significance. However the use of this model for the purpose of predicting yield prior to harvest could be decided based on its performance on other criteria measures.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 0.7188 + 0.0002009\, Q_{(23)1} + 0.0632434\, Q_{(34)2}$$

Table. 46 Step-up regression analysis of the crop forecasting model $S2M2.V_6$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{32}	b_{32}	0.0000236	0.0000097	2.4280*

$S = 10$ $R^2 = 0.4243$ $Ra^2 = 0.3523$

$A_0 = 1.4323$ $t_8 = 2.306$

Table. 47 Step-up regression analysis of the crop forecasting model $S2M3.V_6$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.0005994	0.0002375	2.5240*

$S = 10$ $R^2 = 0.4433$ $Ra^2 = 0.3737$

$A_0 = 2.1915$ $t_5 = 2.306$

Table. 48 Step-up regression analysis of the crop forecasting model $S2M4.V_6$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{31}	a_{31}	0.0083411	0.0009339	8.9313*
Z_{43}	a_{43}	-2.2541117	0.281210	-8.0158*
Z'_{43}	b_{43}	6.3456912	1.0933144	5.8041*
Z'_{21}	b_{21}	-152.8894	17.508398	-8.7323*
$Q_{(14)2}$	$g_{(14)2}$	0.8100659	0.1257131	6.4438*
Z'_{23}	b_{23}	-30.28649	4.802324	-6.2831*
Z_{22}	a_{22}	14.545209	2.0637934	7.0478*

$S = 10$ $R^2 = 0.9936$ $Ra^2 = 0.9714$

$A_0 = 2043.6768$ $t_2 = 4.303$

Table. 49 Step-up regression analysis of the crop forecasting model $S3M2.V_6$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{31}	b_{31}	0.0000198	0.0000054	3.6779*
$Q_{(23)0}$	$g_{(23)0}$	0.0004563	0.0001653	2.4622*

$S = 10$ $R^2 = 0.6633$ $Ra^2 = 0.5671$

$A_0 = 3.3448$ $t7 = 2.365$

Table. 50 Step-up regression analysis of the crop forecasting model $S3M3.V_6$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$\varepsilon_{(34)1}$	0.0005637	0.0002116	2.6636*

$S = 10$ $R^2 = 0.4700$ $R_a^2 = 0.4038$

$A_0 = 1.6814$ $t7 = 2.306$

Table. 51 Step-up regression analysis of the crop forecasting model $S4M3.V_6$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$\varepsilon_{(34)2}$	0.0632434	0.0193824	3.2629*
$Q_{(23)1}$	$\varepsilon_{(23)1}$	0.0002009	0.0001140	1.7634

$S = 10$ $R^2 = 0.7116$ $R_a^2 = 0.6292$

$A_0 = 0.7189$ $t_5 = 2.365$

4.2.7 Statistical analysis of the chosen forecasting model under Variety 7

A total of three models one model each form Season I, Season III and Season IV, were selected under Variety 7

a. Season I

1. $S1M1.V_7$

This forecasting model belonged to the category of square model, in particularly model one, as developed in Chapter III.

$Q_{(14)1}$ was the only variable included in the final crop forecasting model, from the nine preliminary selected variables. Table . 52, which contained the estimated regression coefficient of the predictor variable, along with its standard error and computed t value illustrated the significance of the coefficient of the variable at 5% level of significance. However the usefulness of this model in the field of predicting yield in advance of harvest rests mainly on the peroformance of this model with other criteria measures.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 3.9179 + 0.000093\ Q_{(14)1}$$

b. Season III

1. $S3M1.V_7$

This forecasting model falls in the category of square models, namely model one as developed in Chapter III.

From the nine preliminary variables a group of five predictor variables - Z_{42}', $Q_{(14)0}$, $Q_{(14)1}$, $Q_{(14)2}$ and $Q_{(24)1}$ were included in the final crop forecasting model. The estimated regression coefficients of these predictor variables along with their standard error and computed t value were presented in Table . 53. Out of the coefficients of these five predictor variables only three variables $Q_{(14)0}$, $Q_{(14)1}$ and $Q_{(14)2}$ were found to be significant at 5% level of significance. The adequcay and fit of this model was found to be highly satisfactory and hence this model could be used for the purpose of predicting yield in advance of harvest.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 12.5055 + 0.0270884\, Z_{42}' - 0.0383669\, Q_{(14)0} + 0.0097768\, Q_{(14)1} + 0.0091349\, Q_{(14)2} - 0.0270884\, Q_{(24)1}$$

c. Season IV

1. $S4M3.V_7$

This forecasting model belonged to the model three (square model) category as developed in Chapter III.

$Q_{(34)2}$ was the only variable included in the final crop forecasting model. from the nine preliminary selected variables. The estimated regression coefficients of this predictor variable along with its standard error and computed t value were presented in Table . 54. The coefficient of this variable was found to be significant at

5% level of significance. However the use of this model for prediction purposes could be confirmed only after examining its performance with other criteria measures.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 2.5269 + 0.0670431\ Q_{(34)2}$$

Table. 52 Step-up regression analysis of the crop forecasting model $S1M1.V_7$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(14)1}$	$g_{(14)1}$	0.000093	0.000029	3.2139*

$S = 10$ $R^2 = 0.5635$ $Ra^2 = 0.5090$

$A_0 = 3.9179$ $t_{5\%,9} = 2.262$

Table. 53 Step-up regression analysis of the crop forecasting model $S3M1.V_7$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{42}	b_{42}	0.0270884	0.0178642	1.5163
$Q_{(14)0}$	$g_{(14)0}$	-0.0383669	0.0087738	-4.3729*
$Q_{(14)1}$	$g_{(14)1}$	-0.0097768	0.0022796	-4.2888*
$Q_{(14)2}$	$g_{(14)2}$	0.0091349	0.0033078	2.7617*
$Q_{(24)1}$	$g_{(24)1}$	0.0270884	0.0178650	1.5163*

$S = 10$ $R^2 = 0.9252$ $Ra^2 = 0.8317$

$A_0 = 12.5055$ $t = 2.447$

Table. 54 Step-up regression analysis of the crop forecasting model $S4M3.V_7$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$a_{(34)2}$	0.0670431	0.0166862	4.0179*

$S = 10$ $R^2 = 0.6686$ $Ra^2 = 0.6272$

$A_0 = 2.5269$ $t_8 = 2.306$

4.2.8 Statistical analysis of the chosen forecasting model under Variety 8.

The models under this variety comprised of two models from Season II and four models from Season IV.

a. Season II

1. $S2M3.V_8$

This forecasting model belonged to the model three category (square model) as developed in Chapter III.

Z'_{33} and $Q_{(12)2}$ were the two predictor variables included in the final crop forecasting model from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their computed t value were presented in Table. 55. Of the coefficients of the two variables, only that of variable $Q_{(12)2}$ was found to be significant at 5% level of significance. The use of this model for the purpose of prediction could be decided only after reviewing its performance with other criteria measures.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 34.6267 - 0.0009996\, Z'_{33} + 0.0432971\, Q_{(12)2}$$

2. $S2M4.V_8$

This forecasting model belong to the square root category of models, in particular model four as developed in Chapter III.

Z_{22} and Z_{23}' were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 56. Only the coefficient of the variable Z_{22} was found to be significant at 5% level of significance. Moreover from the R^2 value, the use of this model for the prediction of yield prior to harvest could not be justified until its performance with other criteria measures were taken consideration.

The final form of the crop forecasting model developed through step up regression was

$$Y = 30.6477 + 0.0033475\ Z_{22} - 0.4225298\ Z_{23}'$$

b. Season IV

1. $S4M3.V_8$

This forecasting model belonged to the square model category, particularly model three as developed in Chapter III.

Z_{22} and $Q_{(34)2}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 57. The coefficient of the variable $Q_{(34)2}$ was found to be significant at 5% level of significance. However the use of this model for the purpose of predicting yield in advance of harvest could be finalised only after rating its performance with other criteria measures.

The final crop forecasting model developed through step up regression technique was

$$Y = 30.0049 - 1.2172141 \, Z_{22} + 0.0391524 \, Q_{(34)2}$$

2. $S4M4.V_8$

This forecasting model belonged to the square root model category, namely model four as developed in Chapter III.

Z_{22}, $Q_{(12)0}$, $Q_{(13)0}$, $Q_{(13)1}$ and $Q_{(23)1}$ were the five predictor variables included in the final crop forecasting model from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 58. The coefficients of all the variables except that of variable $Q_{(12)0}$ were found to be significant at 5% level of significance. The adequacy and fit of this model was found to be highly satisfactory and hence this model could be used for the purpose of predicting yield in advance of harvest.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 0.5948 - 0.1829062 \, Z_{22} + 0.5152789 \, Q_{(12)0} + 0.0218581 \, Q_{(13)0} + 0.1986084 \, Q_{(13)1} - 0.2311166 \, Q_{(23)1}$$

3. $SAM5.V_8$

This forecasting model belonged to the square root model category, namely model five as developed in Chapter III.

Z_{33}', $Q_{(13)1}$ and $Q_{(23)1}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 59. The coefficients of all the variables were found to be significant at 5% level of significance. 96.73% of the total variance form the mean of yield response was accounted for by the predictor variables in the fitted crop forecasting model. The adequacy and fit of this model was highly satisfactory and hence could be used for the purpose of predicting yield in advance of harvest.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 6.1334 - 3.9370093\ Z_{33}' - 7.3889775\ Q_{(13)1} + 7.1391158\ Q_{(23)1}$$

4. $SAM6.V_8$

This forecasting model belonged to the model six square root category as developed in Chapter III.

Z_{22}' and $Q_{(34)2}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these predictor variables along with their standard error and computed t value were presented in Table 60. Of the two variables only the coefficient of the variable $Q_{(34)2}$ was found to be significant at 5% level of significance. The adequacy and fit of the model was satisfactory but the use of this model for the purpose of predicting yield could be assessed based on its performance with other criteria measures.

The final crop forecasting model developed through step up regression was

$$Y = 53.9716 - 10.910375\ Z_{22}' + 0.3893911\ Q_{(34)2}$$

Table. 55 Step-up regression analysis of the crop forecasting model S2M3.V_8

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(12)2}$	$a_{(12)2}$	-0.0432971	0.0157307	-2.7524*
Z'_{33}	b_{33}	-0.0009996	0.0004245	-2.3574*

S = 10 R^2 = 0.5817 Ra^2 = 0.4622

A_0 = 34.6267 $t_{5\%,7}$ = 2.365

Table. 56 Step-up regression analysis of the crop forecasting model S2M4.V_8

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{33}	b_{33}	-0.4225298	0.3819876	-1.1061
Z_{22}	a_{22}	0.0033475	0.0010987	3.0467*

S = 10 R^2 = 0.6527 Ra^2 = 0.5534

A_0 = 30.6477 t_7 = 2.365

Table. 57 Step-up regression analysis of the crop forecasting model $S4M3.V_8$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$g_{(34)2}$	0.0391524	0.0135799	2.8831*
Z_{22}	a_{22}	-1.2172141	0.6413261	-1.8980

$S = 10$ $R^2 = 0.7096$ $Ra^2 = 0.6266$

$A_0 = 30.0049$ $t_7 = 2.365$

Table. 58 Step-up regression analysis of the crop forecasting model $S4M4.V_8$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)1}$	$g_{(13)1}$	0.1986084	0.0347224	5.7199*
$Q_{(23)1}$	$g_{(23)1}$	0.2311166	0.0420848	5.4917*
Z_{22}	a_{22}	0.1829062	0.0520959	3.5110*
$Q_{(13)0}$	$g_{(13)0}$	0.0218581	0.0073059	2.9918*
$Q_{(12)0}$	$g_{(12)0}$	0.5152789	0.2210783	2.3308

$S = 10$ $R^2 = 0.9379$ $Ra^2 = 0.8602$

$A_0 = 0.5948$ $t_4 = 2.776$

Table. 59 Step-up regression analysis of the crop forecasting model $S4M5.V_8$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)1}$	$g_{(13)1}$	7.1391158	1.150181	6.207 *
$Q_{(23)1}$	$g_{(23)1}$	-7.3889775	1.2215534	-6.0488*
Z'_{33}	b_{33}	-3.9370093	0.7921101	-4.9703*

$S = 10$ $R^2 = 0.9673$ $Ra^2 = 0.9265$

$A_0 = 6.1334$ $t_6 = 2.447$

Table. 60 Step-up regression analysis of the crop forecasting model $S4M6.V_8$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$g_{(34)2}$	0.3893911	0.1356348	2.8709*
Z'_{22}	b_{22}	-10.90375	6.2665843	-1.7400

$S = 10$ $R^2 = 0.7077$ $Ra^2 = 0.6242$

$A_0 = 53.9716$ $t_7 = 2.365$

4.2.9 Statistical analysis of the chosen forecasting model under Variety 9.

A total of ten models were selected under Variety 9. They were - one model from Season I, two models each from Season II and Season III and five models form Season IV.

a. Season I

1. S1M4.V9

This forecasting model belonged to the square root model category namely model four as developed in Chapter III.

The five predictor variables included in the forecasting model from the nine preliminary selected variables were Z_{31}, Z_{32}, Z_{31}', $Q_{(23)0}$ and $Q_{(34)0}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 61. The coefficient of the three variables namely Z_{32}, Z_{31}', $Q_{(23)0}$ were found to be statistically significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory but the use of this model in the use of this model in the field of predicting yield prior to harvest could be judged only after evaluating its performance with other criteria measures.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 2.9742 + 0.4363927\, Z_{31} - 0.1578284\, Z_{32} + 41.1829063\, Z'_{31} - 9.3398494\, Q_{(23)0} + 1.1567333\, Q_{(34)0}$$

b. Season II

1. $S2M3.V_9$

This forecasting model belonged to the model three square root category as developed in Chapter III.

Z'_{43} and $Q_{(13)1}$ were the two variables introduced into the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficient of these variables along with there standard error and computed t value were presented in Table . 62. Only the coefficient of variable $Q_{(13)1}$ was found to be significant at 5% level of significance. The use of this model for the purpose of predicting of yield prior harvest could be assessed based on its performance with other criteria measures.

The final form of the forecasting model developed through stepup regression regression technique was

$$Y = 4.1561 - 0.0000114\, Z'_{43} + 0.000053\, Q_{(13)1}$$

2. $S2M4.V_9$

This forecasting model belonged to the square root model category, namely model four as developed in Chapter III.

$Z'_{(21)}$, Z_{33} and $Q_{(34)2}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with there standard error and computed t values were represented in Table. 63. All the coefficients, except that of variable $Q_{(34)2}$ were found to be significant at 5% level of significance. The adequacy and fit of the models was satisfactory and hence it could be used for the purpose of predicting yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = 144.1969 - 0.0017935\ Z_{33} + 9.8586893\ Z'_{21} + 0.0167531\ Q_{(34)2}$$

c. Season III

1. $S3M3.V_9$

This forecasting model belonged to the square model category, namely model three as developed in Chapter III.

$Z'_{(32)}$, $Q_{(23)1}$ and $Q_{(34)1}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with there standard error and computed t values were represented in Table . 64. The coefficients of all the variables except that of variable Z_{32}' were found to be significant at 5% level of significance. The adequacy and fit of the models was found to be satisfactory but the use of this model for prediction purposes could be judged based on its performance with other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 5.5216 + 0.0000137 Z_{32}' - 0.0007967 Q_{(23)1} + 0.0000855 Q_{(34)1}$$

2. $S3M5.V_9$

This forecasting model belonged to the square root model category, namely model five developed in Chapter III.

$Z_{(32)}$ and $Q_{(23)2}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with there standard error and computed t values were illustrated in Table. 65. The coefficient of all the variable $Q_{(23)2}$ was found to be significant at 5% level of significance. The use of this model for the purpose of predicting yield prior to harvest could be decided on the basis of its performance with other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 10.8679 + 0.0124669\ Z_{32} - 0.149249\ Q_{(23)2}$$

d. Season IV

1. $S4M2.V_9$

This forecasting model belonged to the square model category, namely model two as developed in Chapter III.

Z_{33}, $Q_{(23)1}$ and $Q_{(34)2}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with there standard error and computed t values were presented in Table. 66. The coefficients of all the variables except that of variable $Q_{(34)2}$ were found to be significant at 5% level of significance. However the use of this model for the purpose of predicting yield could be assessed based on its performance with other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 5.9901 + 1.3521224\ Z_{33} - 0.0654496\ Q_{(23)1} + 0.0200639\ Q_{(34)2}$$

2. $S4M3.V_9$

This forecasting model belonged to the square model category, namely model two as developed in Chapter III.

The six predictor variables introduced in the final crop forecasting model, from the nine preliminary selected variables were Z_{12}', Z_{22}', Z_{32}', $Q_{(23)1}$, $Q_{(24)1}$ and $Q_{(34)2}$. The estimated regression coefficients of these variables along with there standard error and computed t values were illustrated in Table. 67. Of the six variables, the coefficient of four variables namely Z_{12}', Z_{32}', $Q_{(24)1}$ and $Q_{(34)2}$ were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be used for the purpose of predicting yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = 2.9431 + 0.0029473\ Z_{12}' - 0.0039648\ Z_{22}' - 0.000086\ Z_{32}' - 0.0000224\ Q_{(23)1} + 0.0017905\ Q_{(24)1} + 0.0633646\ Q_{(34)2}$$

3. CAMA.V$_9$

This forecasting model belonged to the square root model category, in particular model four as developed in Chapter III.

Z_{21}, Z_{32}, Z_{33} and Z_{33}' were the four predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with there standard error and computed t values were presented in Table . 68. Of the four predictor variables, the coefficients of only two variables namely Z_{33} and Z_{33}' were found to be significant at 5% level of significance. The adequacy and fit of this model was found to be satisfactory, but the use of this model for the purpose of predicting yield prior to harvest could be ascertained only after studying its influence on other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 34.8313 - 0.2315091\ Z_{21} + 0.0026503\ Z_{32} - 0.0026853\ Z_{33} + 0.0201259\ Z_{33}'$$

4. $S4M5.V_9$

This forecasting model belonged to the square root model category, in particular model five as developed in Chapter III.

The four predictor variables included in the final crop forecasting model, from the nine preliminary selected variables were Z_{21}, Z_{32}, Z_{33} and Z_{33}'. The estimated regression coefficients of these variables along with there standard error and computed t values were presented in Table. 69. The coefficients of only two variables namely Z_{33} and Z_{33}' were found to be statistically significant at 5% level of significance. The adequacy and fit of this model was found to be satisfactory, but the use of this model for the purpose of predicting yield prior to harvest could be ascertained on the basis of its influence on other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 37.0805 - 1.4940509\, Z_{21} + 0.0556902\, Z_{32} - 0.2472386\, Z_{33} + 1.8872753\, Z_{33}'$$

5. $S4M6.V_9$

This forecasting model belonged to the category of square root models, namely the model six as developed in Chapter III.

$Q_{(24)1}$ and $Q_{(34)2}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables in combination with there standard error and computed t values were presented in Table. 70. The coefficient of variable namely $Q_{(34)2}$ was found significant at 5% level of significance. The adequacy and fit of this model was found to be highly satisfactory, and hence it could be used for the purpose of predicting yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = 1.7671 + 0.0449764\, Q_{(24)1} + 0.5734437\, Q_{(34)2}$$

Table. 61 Step-up regression analysis of the crop forecasting model $S1M4.V_9$

Z'_{31}	b_{31}	41.1829063	14.993063	2.7468*
$Q_{(23)0}$	$g_{(23)0}$	-9.3398494	3.252783	-2.8713*
$Q_{(34)0}$	$g_{(34)0}$	1.1567333	0.5851581	1.9768
Z_{31}	a_{31}	0.4363927	0.2104618	2.0735
Z_{32}	a_{32}	-0.1578284	0.0401627	-3.9299*

$S = 10$ $R^2 = 0.8407$ $Ra^2 = 0.6164$

$A_0 = 2.9742$ $t_4 = 2.776$

Table. 62 Step-up regression analysis of the crop forecasting model $S2M3.V_9$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)1}$	$g_{(13)1}$	0.0000537	0.0000168	3.1151*
Z'_{43}	b_{43}	-0.0000114	0.0000068	-1.6619

$S = 10$ $R^2 = 0.7172$ $Ra^2 = 0.6364$

$A_0 = 4.1561$ $t_{5\%,7} = 2.365$

Table. 63 Step-up regression analysis of the crop forecasting model $S2M4.V_9$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{33}	a_{33}	-0.0017935	0.0005312	-3.3761*
$Q_{(34)2}$	$g_{(34)2}$	0.0167531	0.0095616	1.7521
Z'_{21}	b_{21}	9.8586893	3.6468358	2.7034*

S = 10 R^2 = 0.8322 Ra^2 = 0.7483

A_0 = 144.1969 t_6 = 2.447

Table. 64 Step-up regression analysis of the crop forecasting model $S3M3.V_9$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(23)1}$	$g_{(23)1}$	-0.0007967	0.0002648	6.5216*
$Q_{(34)1}$	$g_{(34)1}$	0.0000855	0.0000341	2.5066*
Z'_{32}	b_{32}	0.0000137	0.0000063	2.1714

S = 10 R^2 = 0.7694 Ra^2 = 0.6541

A_0 = 5.5216 t_6 = 2.447

Table. 65 Step-up regression analysis of the crop forecasting model $S3M5.V_9$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(23)2}$	$g_{(23)2}$	-0.1492490	0.0554440	-2.6919*
Z'_{32}	a_{32}	0.0124669	0.0110591	1.1273

$S = 10$ $R^2 = 0.6245$ $Ra^2 = 0.5775$

$A_0 = 10.8679$ $t_7 = 2.365$

Table. 66 Step-up regression analysis of the crop forecasting model $S4M2.V_9$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(23)1}$	$g_{(23)1}$	-0.0654496	0.0234052	-2.7964*
Z_{33}	a_{33}	1.3521224	0.5242146	2.5793*
$Q_{(34)2}$	$g_{(34)2}$	0.0200639	0.0116201	1.7267

$S = 10$ $R^2 = 0.7055$ $Ra^2 = 0.5583$

$A_0 = 5.9901$ $t_6 = 2.447$

Table. 67 Step-up regression analysis of the crop forecasting model $S4M3.V_9$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$g_{(34)2}$	0.0633646	0.0093065	6.8086*
Z'_{12}	b_{12}	0.0029473	0.0007017	4.2001*
$Q_{(24)1}$	$g_{(24)1}$	0.0017905	0.0004031	4.4416
$Q_{(23)1}$	$g_{(23)1}$	-0.0000224	0.0000133	-1.6881
Z'_{22}	b_{22}	-0.0039648	0.0016408	-2.4169
Z'_{32}	b_{32}	-0.000086	0.0000248	-3.5087*

$S = 10$ $R^2 = 0.9846$ $Ra^2 = 0.9538$

$A_0 = 2.9431$ $t_3 = 3.182$

Table. 68 Step-up regression analysis of the crop forecasting model $S4M4.V_9$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{33}	a_{33}	-0.0026853	0.0006558	-4.0948*
Z_{32}	a_{32}	0.0026503	0.0016451	1.6116
Z_{21}	a_{21}	-0.2315091	0.1365212	-1.6958
Z'_{33}	b_{33}	0.0201259	0.0046410	4.3365*

$S = 10$ $R^2 = 0.8813$ $Ra^2 = 0.7863$

$A_0 = 34.8313$ $t_5 = 2.571$

4.2.10 Statistical analysis of the chosen forecasting model under Variety 10.

A total of ten models were selected under this variety. They were five models from Season II, one model from Season III and four models from Season IV.

a. Season II.

1. $S2M1.V_{10}$

This forecasting model belonged to the square model category, more precisely the model one as developed in Chapter III.

The five predictor variables in the crop forecasting model from the nine preliminary selected variables were Z_{42}, Z'_{42}, $Q_{(14)2}$, $Q_{(23)2}$, and $Q_{(24)2}$. The estimated regression coefficients of those variables along with their standard error and computed t values were presented in Table . 71. The coefficient of variable except those of $Q_{(14)2}$ and $Q_{(23)2}$ were found to be statistically significant at 5% level of significance. The adequacy and fit of this model was found to be highly satisfactory, and hence it could be used for the purpose of predicting yield prior to harvest.

The final form of the crop forecasting model developed through step up regression techniques was

$$Y = -277.7705 + 23.746421 Z_{42} - 0.6800071 Z'_{42} + 0.2904587 Q_{(14)2} + 0.0000221 Q_{(23)2} + 0.3672072 Q_{(24)2}$$

2. $S2M2.V_{10}$

This forecasting model belonged to the square model category, namely the model two as developed in Chapter III.

The six predictor variables in the crop forecasting model from the nine preliminary selected variables were Z_{42}, Z'_{42}, Z_{43}, $Q_{(14)2}$, and $Q_{(24)2}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 72. The adequacy and fit of the model was found to be satisfactory, but its use for the purpose of predicting yield could be verified on the basis of its performance with other criteria measures.

The final crop forecasting model obtained through step up through step up regression techniques was

$$Y = 71.1032 - 2.4103643\ Z'_{42} + 7.2644109\ Z_{42} + 5.1920046\ Z_{43} + 0.3512773\ Q_{(14)2} + 0.1728883\ Q_{(24)2}$$

3. $S2M3.V_{10}$

This forecasting model belonged to the square model category, namely the model three as developed in Chapter III.

The six predictor variables included in the crop forecasting model from the nine preliminary selected variables were Z_{41}, $Q_{(13)1}$, $Q_{(14)1}$, $Q_{(23)1}$, $Q_{(24)2}$ and $Q_{(34)1}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 73. The coefficients of all the variables were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be used for the purpose of predicting the yield prior to harvest.

The final crop forecasting model obtained through step up through step up regression techniques was

$$Y = 8.5023 - 0.0565195\, Z_{41} + 0.0041668\, Q_{(13)1} - 0.1389832\, Q_{(14)1} - 0.0047912\, Q_{(23)1} + 0.145406\, Q_{(24)2} + 0.0010902\, Q_{(34)1}$$

4. $S2M4.V_{10}$

This forecasting model belonged to the square model category, namely the model three as developed in Chapter III.

The six predictor variables included in the crop forecasting model from the nine preliminary selected variables were Z_{33}', Z_{42}', Z_{43}', $Q_{(13)2}$ and $Q_{(14)2}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 74. The coefficients of all the variables were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be used for the purpose of predicting the yield prior to harvest.

The final crop forecasting model obtained through step up regression techniques was

$$Y = -5.3035 - 2.7751171\ Z'_{33} + 25.639271\ Z'_{43} + 0.0558393\ Z'_{42} + 0.485944\ Q_{(13)2} - 4.4738836\ Q_{(14)2}$$

5. S2M5.V_{10}

This forecasting model belonged to the square root model category, namely the model five as developed in Chapter III.

The five predictor variables included in the crop forecasting model from the nine preliminary selected variables were Z_{43}, Z'_{42}, Z'_{43}, $Q_{(12)2}$ and $Q_{(23)2}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 75. The coefficients of all the variables were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be used for the purpose of predicting the yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = -459.5655 + 57.971706\ Z_{43} - 115.29861\ Z'_{42} + 387.0706\ Z'_{43} + 5.7382168\ Q_{(12)2} - 0.095473\ Q_{(23)2}$$

b. Season III

1. $S3M3.V_{10}$

This forecasting model belonged to the category of square models in particular the model three as developed in Chapter III.

Z_{13}, Z_{32}, Z_{12}', $Q_{(23)1}$ and $Q_{(34)1}$ were the five predictor variables included in the crop forecasting model from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 76. The coefficients of all the variables were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be used for the purpose of predicting the yield in advance of harvest.

The final crop forecasting model developed through step up regression was

$$Y = 151.6340 - 14.009807\ Z_{13} - 0.0258027\ Z_{32} + 0.2917277\ Z_{12}' + 0.0003407\ Q_{(23)1} + 0.0016056\ Q_{(34)1}$$

c. Season IV

1. $S4M2.V_{10}$

This forecasting model belonged to the square model category, namely the model two as developed in Chapter III.

The three predictor variables included in the final crop forecasting model from the nine preliminary selected variables were Z_{33}, Z'_{12} and Z'_{13}. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 77. The coefficients of all the variables were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory and hence this model could also be used for the purpose of predicting the yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = 9.1401 + 0.0004286\, Z'_{12} - 0.000414\, Z'_{13} + 0.1049704\, Z_{33}$$

2. S4M4.V_{10}

This forecasting model belonged to the category of square models, particularly the model four developed in Chapter III.

The six predictor variables included in the crop forecasting model from the nine preliminary selected variables were Z_{12}, Z_{33}, Z'_{13}, $Q_{(34)0}$, $Q_{(34)1}$ and $Q_{(34)2}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 78. The coefficients of all the variables except that of Z_{12} were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory and hence this model could also be used for the purpose of predicting the yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = -3.9418 - 0.0011951\ Z_{33} + 0.0025162\ Z_{12} + 0.0042738\ Z_{13}' + 0.0723936\ Q_{(34)0} - 0.0017431\ Q_{(34)1} + 0.0067155\ Q_{(34)2}$$

3. $S4M5.V_{10}$

This forecasting model belonged to the square root model category, particularly the model five as developed in Chapter III.

The two predictor variables included in the crop forecasting model, from the nine preliminary selected variables were Z_{33}, and $Q_{(34)1}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 79. The coefficients of both the variables were found to be significant at 5% level of significance. However the use of this model for the purpose of predicting the yield prior to harvest could be adjudged based on its performance wiht other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 1.5847 - 0.1399197\ Z_{33} + 0.70205913\ Q_{(34)1}$$

4. $SAM6.V_{10}$

This forecasting model belonged to the category of square root models, namely the model six as developed in Chapter III.

The three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables were Z_{12} and $Q_{(34)2}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 80. The coefficients of these variables were found to be significant at 5% level of significance. The adequacy and fit of this model was found to be highly satisfactory and hence this model can be used for the purpose of predicting the yield in advance of harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = 34.1422 + 1.0673601\ Z_{12} + 0.6303036\ Q_{(34)2}$$

Table. 71 Step-up regression analysis of the crop forecasting model $S2M1.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(23)2}$	$g_{(23)2}$	0.0000221	0.0000121	1.8240
$Q_{(14)2}$	$g_{(14)2}$	0.2904587	0.1077688	2.6952
Z_{42}	b_{42}	-0.6800071	0.1867127	-3.6420*
$Q_{(24)2}$	$g_{(24)2}$	0.3672072	0.0404869	9.0698*
Z_{42}	a_{42}	23.746421	4.8306608	-4.9158*

S = 10 R^2 = 0.9619 Ra^2 = 0.9143

A_0 = -277.7705 t_4 = 2.776

Table. 72 Step-up regression analysis of the crop forecasting model $S2M2.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{43}	a_{43}	5.1920046	4.3897962	1.1827
$Q_{(14)2}$	$g_{(14)2}$	0.3512773	0.1890702	1.8579
$Q_{(24)2}$	$g_{(24)2}$	0.1728883	0.1005474	1.7195
Z_{42}	a_{42}	7.2644109	2.7396974	2.6515
Z'_{42}	b_{42}	2.4103643	0.4181849	5.7639*

S = 10 R^2 = 0.9425 Ra^2 = 0.8706

A_0 = 71.1082 t_3 = 3.182

Table. 73 Step-up regression analysis of the crop forecasting model $S2M3.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.0010902	0.0001216	8.9627*
$Q_{(13)1}$	$g_{(13)1}$	0.0041668	0.0006807	6.1214*
Z_{41}	a_{41}	-0.0565195	0.0064724	-8.7324*
$Q_{(23)1}$	$g_{(23)1}$	-0.0047912	0.0008346	-5.7406*
$Q_{(24)2}$	$g_{(24)2}$	0.1454060	0.0367571	3.9559*
$Q_{(14)1}$	$g_{(14)1}$	-0.1389832	0.0287866	-4.8281*

$S = 10$ $R^2 = 0.9937$ $Ra^2 = 0.9717$

$A_0 = 8.5023$ $t_3 = 3.182$

Table. 74 Step-up regression analysis of the crop forecasting model $S2M4.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{43}	b_{43}	25.639271	4.2201361	6.0755*
$Q_{(13)2}$	$g_{(13)2}$	0.4859440	0.0916106	5.3045*
Z_{33}	b_{33}	2.7751171	0.5172769	5.3649*
$Q_{(14)2}$	$g_{(14)2}$	4.4738836	0.7464847	5.9933*
Z'_{42}	b_{42}	0.0558393	0.0118748	4.7024*

$S = 10$ $R^2 = 0.9492$ $Ra^2 = 0.8856$

$A_0 = -5.3035$ $t_4 = 2.776$

Table. 75 Step-up regression analysis of the crop forecasting model $S2M5.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{43}	b_{43}	387.07060	47.795581	8.0985*
$Q_{(12)2}$	$g_{(12)2}$	5.7382168	1.1672271	4.9161*
$Q_{(23)2}$	$g_{(23)2}$	-0.095473	0.0216221	-4.4155*
Z_{43}	a_{43}	57.971706	7.3764872	7.8590*
Z'_{42}	b_{42}	-115.29861	16.017989	-7.1981*

$S = 10$ $R^2 = 0.9699$ $Ra^2 = 0.9324$

$A_0 = -459.5655$ $t_4 = 2.776$

Table. 76 Step-up regression analysis of the crop forecasting model $S3M3.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.0016056	0.0002861	5.6112*
Z_{32}	a_{32}	-0.0258027	0.0036631	7.0439*
$Q_{(23)1}$	$g_{(23)1}$	0.00034077	0.0000423	8.0603*
Z_{13}	a_{13}	14.009807	5.1980586	-2.6952
Z'_{12}	b_{12}	0.2917277	0.0850604	3.4297*

$S = 10$ $R^2 = 0.9756$ $Ra^2 = 0.9269$

$A_0 = 151.6340$ $t_4 = 2.776$

Table. 77 Step-up regression analysis of the crop forecasting model $S4M2.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{13}	b_{13}	-0.000414	0.0001221	-3.3909*
Z_{33}	a_{33}	0.1049704	0.0327551	3.2047*
Z'_{12}	b_{12}	0.0004286	0.0001321	3.2449*

$S = 10$ $\quad R^2 = 0.8654$ $\quad Ra^2 = 0.7649$

$A_0 = 9.1401$ $\quad t_6 = 2.447$

Table. 78 Step-up regression analysis of the crop forecasting model $S4M4.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{33}	a_{33}	-0.0011951	0.0001584	-7.5432*
$Q_{(34)0}$	$g_{(34)0}$	0.0723936	0.0123752	5.8499*
$Q_{(34)2}$	$g_{(34)2}$	-0.0017431	0.0001882	-9.2624*
Z'_{13}	b_{13}	0.0042738	0.0024037	3.4877*
$Q_{(34)2}$	$g_{(34)2}$	0.0067155	0.0010037	6.6909*
Z'_{12}	b_{12}	0.0025162	0.0008704	-2.8910

$S = 10$ $\quad R^2 = 0.9879$ $\quad Ra^2 = 0.9637$

$A_0 = -3.9418$ $\quad t_3 = 3.182$

Table. 79 Step-up regression analysis of the crop forecasting model $S4M5.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{33}	a_{33}	-0.1399197	0.0491488	-2.8469*
$Q_{(34)1}$	$g_{(34)1}$	0.7020513	0.2678128	2.6214*

S = 10 R^2 = 0.6131 Ra^2 = 0.5025

A_0 = 1.5847 t_7 = 2.365

Table. 80 Step-up regression analysis of the crop forecasting model $S4M6.V_{10}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$g_{(34)2}$	0.6303036	0.1872017	3.3670*
Z_{12}	a_{12}	1.0673601	0.4111823	2.5958*

S = 10 R^2 = 0.8223 Ra^2 = 0.7716

A_0 = -34.1422 t_7 = 2.365

4.2.12 Statistical analysis of the chosen forecasting models under Variety 12.

A total of three models were selected under Variety 12. They were two models from Season II, one model from Season III and Season IV.

a. Season II

1. $S2M2.V_{12}$

This forecasting model belonged to the category of square models, namely model two as developed in Chapter III.

The five predictor variables included in the final crop forecasting model, from the nine preliminary selected variables were Z_{21}, Z_{22}, Z_{43}, Z_{22}'and Z_{43}'. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 81. The coefficients of all variables except that of Z_{22}' were found to be significant at 5% level of significance. The adequacy and fit of this model was found to be highly satisfactory and hence this model can be used for the purpose of predicting the yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = 82.694 - 5.9361127\ Z_{21} + 0.0692768\ Z_{22}' + 0.01318951\ Z_{22} + 6.0371088\ Z_{43} - 0.434729\ Z_{43}'$$

2. S2M3.V_{12} .

This forecasting model belonged to the category of square models, namely model three as developed in Chapter III.

$Q_{(13)1}$, $Q_{(23)1}$ and $Q_{(34)1}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables were . The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 82. The coefficients of all variables except that of variable $Q_{(23)1}$ ' were found to be significant at 5% level of significance. The adequacy and fit of this model was found to be satisfactory but the use of this model for the purpose of predicting the yield prior to harvest could be judged based on its performance with other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 1.4880 + 0.0000109\, Q_{(13)1} + 0.0000607\, Q_{(23)1} + 0.0001407\, Q_{(34)1}$$

b. Season III

1. S3M6.V_{12}

This forecasting model belonged to the category of square root models, namely the model six as developed in Chapter III.

The six predictor variables included in the final crop forecasting model, from the nine preliminary selected variables were Z_{32}, Z_{32}', Z_{33}', $Q_{(23)1}$, $Q_{(23)2}$ and $Q_{(34)1}$. The estimated regression coefficients of these variables along with their standard error and computed t values were illustrated in Table. 83. The coefficients of all variables except that of Z_{32} and Z_{32}' were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and hence this model could be utilised for the purpose of predicting the yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = 6.4338 - 0.0044386\, Z_{32} + 0.000167\, Z_{32}' - 0.3929077\, Z_{33}' + 0.0009\, Q_{(23)1} + 0.0008413\, Q_{(23)2} - 0.0009791\, Q_{(34)1}$$

Table. 81 Step-up regression analysis of the crop forecasting model $S2M2.V_{12}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{21}	a_{21}	-5.9360127	1.8933973	-3.1351*
Z_{22}	a_{22}	0.0138951	0.0032096	4.3293*
Z_{22}	b_{22}	0.0692768	0.0328783	2.1071
Z_{43}	a_{43}	6.0371088	1.8601637	3.2455*
Z_{43}	b_{43}	-0.434729	0.1555404	-2.7950*

S = 10 R^2 = 0.9192 Ra^2 = 0.8183

A_0 = 82.6940 t_7 = 2.776

Table. 82 Step-up regression analysis of the crop forecasting model $S2M3.V_{12}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.0001407	0.0000423	3.3280*
$Q_{(13)1}$	$g_{(13)1}$	0.0000109	0.0000044	2.4764*
$Q_{(23)1}$	$g_{(23)1}$	0.0000607	0.0000401	1.5142

S = 10 R^2 = 0.7649 Ra^2 = 0.6473

A_0 = 1.4880 t_6 = 2.447

Table. 83 Step-up regression analysis of the crop forecasting model S3M6.V_{12}

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{32}	b_{32}	0.0001670	0.0086935	0.0192
Z_{33}	b_{33}	-0.3929077	0.0645332	-6.0885
$Q_{(34)1}$	$g_{(34)1}$	-0.0009791	0.000162	-6.0428*
$Q_{(23)1}$	$g_{(23)1}$	0.000900	0.0001693	5.1367*
Z_{32}	a_{32}	-0.0044386	0.0016632	-2.6686
$Q_{(23)2}$	$g_{(23)2}$	0.0008413	0.0001359	-6.1919*

S = 10 R^2 = 0.9781 Ra^2 = 0 9344

A_0 = 6.4338 t_3 = 3.182

4.2.13 Statistical analysis of the chosen forecasting models under Variety 13

A total of eight models, two from Season I, one from Season II, two from Season III and three from Season IV.

a. Season I

1. $S1M2.V_{13}$

This forecasting model belonged to the category of square models, namely model two as developed in Chapter III.

Z_{12} and Z_{13} were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 84. The coefficients of both the variables were significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory but its use for the purpose of predicting the yield depends on its performance with other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 22.6443 + 5.9043049\ Z_{12} \quad 4.996495\ Z_{13}$$

2. $S1M5.V_{13}$

This forecasting model belonged to the category of square root models, namely the model five as developed in Chapter III.

Z'_{12}, Z'_{13}, $Q_{(12)1}$ and $Q_{(24)2}$ were the four predictor variables included in the crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table 85. The coefficients of both the variables were found significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and hence it could be used for the purpose of predicting the yield prior to harvest.

The final crop forecasting model developed through step up regression techniques was

$$Y = -3529.5004 - 106.09652\, Z'_{12} + 1125.9155\, Z'_{13} + 18.569807\, Q_{(12)1} + 1.7294777\, Q_{(24)2}$$

b. Season II

1. $32M4.V_{13}$

This forecasting model belonged to the square root model category, namely the model four as developed in Chapter III.

Z'_{33} and $Q_{(13)2}$ were the two predictor variables included in the crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 86. Only the coefficient of the variable $Q_{(13)2}$ was found to be significant at 5% level of significance. However the use of this model for the purpose of predicting the yield in advance of harvest could be judged based on its performance with other criteria measures.

The final crop forecasting model developed through step up regression techniques was

$$Y = 11.9497 + 0.0179907\, Z_{33}' - 0.0039206\, Q_{(13)2}$$

c. Season III

1. S3M1.V_{13}

This forecasting model belonged to the category of square models, particularly the model one as developed in Chapter III.

Z_{13}, Z_{33}, Z_{12}', $Q_{(23)2}$ and $Q_{(34)2}$ were the four predictor variables included in the crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table 87. The coefficients of all the variables except those of variables Z_{12}' and $Q_{(34)2}$ were found significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and could be used for the purpose of predicting the yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 187.0637 + 0.6792843\, Z_{13} - 0.003314\, Z_{33} - 0.0187031\, Z'_{12} + 0.0000061\, Q_{(23)2} + 0.0001955\, Q_{(34)2}$$

2. $S3M3.V_{13}$

This forecasting model belonged to the categong of square models namely the model three as developed in Chapter III.

$Q_{(13)1}$, $Q_{(23)1}$, $Q_{(34)1}$ and $Q_{(34)2}$ were the four predictor variables encluded in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficient of these variables along with their standard error computed t values were presented in Table . 88. The coefficient of all the predictor variables were found to be significant at 5% level of significance. The adequacy and fit of the model was highly satisfactory and it could be used for the purpose of predicting yield prior to harvest.

The final form of the crop forecasting model developed through step up regression was

$$Y = 2.6817 + 0.0001375\, Q_{(13)1} - 0.0000351\, Q_{(23)1} - 0.0024922\, Q_{(24)1} + 0.0020952\, Q_{(34)2}$$

d. Season IV

1. $SAMA.V_{13}$

This forecasting model belonges to the category of square root model. particularly the model four as developed in Chapter III.

Z_{21}, Z_{12}', Z'_{13} were the three predictor variables concluded in the crop forecasting model. from the nine preliminary selected variables. The estimated regression coefficient of these variables with their standard error and computed t values were presented in Table. 89. The coefficient of all the three variables were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory and hence it could be used for the purpose of predicting yield prior to harvest.

The final form of the crop forecasting model developed through step up regression was

$$Y = 3.8673 - 1.8952899\ Z_{13}' - 1.562601\ Z_{21} + 12.927157\ Z'_{12}$$

2. $SAM5.V_{13}$

This forecasting model belonged to the category of square root model, particularly the model five as developed in Chapter III.

Z_{13}, Z_{11}', Z'_{21} were the three predictor variables included in the crop forecasting model. from the nine preliminary selected variables. The estimated regression coefficient of these variables with their standared error computed t values were presented in Table . 90. The coefficient of all the variables were found to be significant at 5% level of significance. The adequacy and fit of the model was satisfactory and hence it could be used for the purpose of predicting yield prior to harvest.

The final form of the crop forecasting model developed through step up regression was

$$Y = 261.2455 + 52.670121\ Z13 - 53.670121\ Z11' + 26.541812\ Z'_{21} .$$

3. $S4M6.V_{13}$

This forecasting model belonged to the category of square root models, particularly the model namely the model six as developed in Chapter III.

Z_{32} was the only variable included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 91. The coefficients of the variable was found to be significant. However the use of this model for the purpose of predicting yield prior to harvest could be ascertained on the basis of its performance with other criteria measures.

The final form of crop forecasting model was

$$Y = 4.8688 + 0.1945132\ Z_{32}'$$

Table. 84 Step-up regression analysis of the crop forecasting model S1M2.V_{13}

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{13}	a_{13}	-4.992495	1.5970966	-3.1285*
Z_{12}	a_{12}	5.9043049	1.6505799	3.5771

$S = 10$ $R^2 = 0.6468$ $Ra^2 = 0.5458$

$A_0 = 22.6443$ $t_7 = 2.365$

Table. 85 Step-up regression analysis of the crop forecasting model S1M5.V_{13}

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{13}	b_{13}	1125.9155	176.06794	6.3948*
Z_{12}	b_{12}	-106.09652	17.474462	-6.0715*
$Q_{(12)1}$	$g_{(12)1}$	18.569807	3.2837436	5.6551*
$Q_{(24)2}$	$g_{(24)2}$	1.7294777	0.2269926	7.6191*

$S = 10$ $R^2 = 0.9367$ $Ra^2 = 0.8861$

$A_0 = -3529.5004$ $t_5 = 2.571$

Table. 86 Step-up regression analysis of the crop forecasting model $S2M4.V_{13}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{33}	b_{33}	-0.0179907	0.0094713	-1.8995
$Q_{(13)2}$	$g_{(13)2}$	-0.0039206	0.00125130	-3.1333*

$S = 10$ $R^2 = 0.6395$ $Ra^2 = 0.5365$

$A_0 = 11.9497$ $t_7 = 2.365$

Table. 87 Step-up regression analysis of the crop forecasting model $S3M1.V_{13}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{13}	a_{13}	0.6792843	0.2433276	2.7916*
Z_{12}	b_{12}	-0.0187031	0.0086385	-2.1651
$Q_{(23)2}$	$g_{(23)2}$	0.0000061	0.0000012	5.2612*
$Q_{(34)2}$	$g_{(34)2}$	0.0001955	0.0000753	2.5982*
Z_{33}	a_{33}	-0.003314	0.0006580	-5.0368*

$S = 10$ $R^2 = 0.9229$ $Ra^2 = 0.8266$

$A_0 = 187.0637$ $t_4 = 2.776$

Table. 88 Step-up regression analysis of the crop forecasting model $S3M3.V_{13}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	-0.0024922	0.0008652	-2.8807*
$Q_{(23)1}$	$g_{(23)1}$	-0.0000351	0.0000123	-2.8491*
$Q_{(13)1}$	$g_{(13)1}$	0.0001375	0.0000383	3.5854*
$Q_{(34)2}$	$g_{(34)2}$	0.0020952	0.0072059	2.9076*

$S = 10$ $R^2 = 0.8255$ $Ra^2 = 0.7383$

$A_0 = 2.6817$ $t_5 = 2.571$

Table. 89 Step-up regression analysis of the crop forecasting model $S4M4.V_{13}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{13}	b_{13}	-1.8952899	0.6038301	-3.1388*
Z_{12}	b_{12}	12.927157	3.3589005	3.8486*
Z_{21}	a_{21}	-1.562501	0.3122205	-5.0045*

$S = 10$ $R^2 = 0.8423$ $Ra^2 = 0.7635$

$A_0 = 3.8673$ $t_6 = 2.447$

Table. 90 Step-up regression analysis of the crop forecasting model $S4M5.V_{13}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{13}	a_{13}	52.670121	1.3613489	3.869 *
Z'_{11}	b_{11}	-53.649425	17.923158	-2.9933*
Z'_{21}	b_{21}	-26.541812	5.8492522	-4.5376*

S = 10 R^2 = 0.8172 Ra^2 = 0.7259

A_0 = 261.2455 t_6 = 2.447

Table. 91 Step-up regression analysis of the crop forecasting model $S4M6.V_{13}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{32}	b_{32}	0.1945132	0.0815724	2.3845*

S = 10 R^2 = 0.4155 Ra^2 = 0.3424

A_0 = 4.8683 t_8 = 2.306

4.2.14 Statistical analysis of the chosen forecasting model under variety 14

A total of three models were selected under this variety ie. one model each from Season I, Season II and Season III.

a. Season I

1. $S1M6.V_{14}$

This forecasting model belonged to the category of square root models, particularly the model six as developed in Chapter III.

Z_{13}, Z_{22}, Z_{33}', $Q_{(12)2}$ and $Q_{(34)1}$ were the five predictor variables included in the crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of the variables Z_{22} and Z_{33} 'were found to be significant at 5% level of significance. Though 81.79% of the total variance from the mean in yield response could be accounted for by these predictor variables in the final crop forecasting model the use of this model for the purpose of predicting yield price to advance dould judged based on its performance with other criteria measures

The final form of crop forecasting model developed through step up regression technique was

$$Y = 12.5964 + 0.0116811\ Z_{13} + 0.6759552\ Z_{22} + 2.7333726\ Z_{33} + 0.0350071\ Q_{(12)2} - 0.059845\ Q_{(34)1}$$

b. Season II

1. $S2M6.v_{14}$

This forecasting model belonged to the category of square root models namely the model six as developed in Chapter III.

$Q_{(34)1}$ was the only variable included in the final crop forecasting model from the nine preliminary selected variables. The estimated regression coefficient of this variable along with its standard error and computed value were presented in Table. 93. The coefficient of the variable was found to be significant at 5% level of significance, but the use of this model for the purpose of predicting yield prior to harvest could be ascertained on the basis of its performance with other criteria measures.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 3.4576 - 0.0001437 \, Q_{(34)1}$$

c. Season III

1. $S3M3.V_{14}$

This forecasting model belonged to the category of square model, namely the model three as developed in Chapter III.

Z_{22}, Z_{33}, Z_{22}', $Q_{(12)1}$, $Q_{(13)1}$, $Q_{(23)1}$ and $Q_{(34)1}$ were the predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables.

variables along with their standard error and computed t values were presented in Table. 94. The coefficients of all the variables except those of Z_{33} and $Q_{(12)1}$ were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and the use of this model for the purpose of predicting yield prior to harvest could be comprehended without indecision

The final form of the crop forecasting model developed through step up regression technique was

$$
\begin{aligned}
Y = \; & 16.0861 + 14.369455\, Z_{22} + 0.0055701\, Z_{33} \\
& \quad 0.3279953\, Z_{22} + 0.0051581\, Q_{(12)1} \\
& + 0.0000833\, Q_{(13)1} \quad 0.000035\, Q_{(23)1} \\
& \quad 0.0003881\, Q_{(34)1}
\end{aligned}
$$

Table. 92 Step-up regression analysis of the crop forecasting model $S1M6.V_{14}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{22}	a_{22}	0.6759552	0.2156309	3.1348*
Z'_{33}	b_{33}	2.7333726	0.9145554	2.9887*
$Q_{(34)1}$	$g_{(34)1}$	-0.0598450	0.0238711	-2.5076
Z_{13}	a_{13}	0.0116811	0.0058292	2.2981
$Q_{(12)2}$	$g_{(12)2}$	-0.0350071	0.0244185	-1.4336

$S = 10$ $R^2 = 0.8179$ $Ra^2 = 0.5903$

$A_0 = 12.5964$ $t_4 = 2.776$

Table. 93 Step-up regression analysis of the crop forecasting model $S2M6.V_{14}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	-0.0001437	0.0000541	-2.6552*

$S = 10$ $R^2 = 0.4684$ $Ra^2 = 0.4020$

$A_0 = 3.4576$ $t_8 = 2.306$

Table. 94 Step-up regression analysis of the crop forecasting model $S3M3.V_{14}$

VARIABLE SELECTED	REGRESSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	-0.0003881	0.0000563	-6.9004*
$Q_{(23)1}$	$g_{(23)1}$	-0.0000035	0.0000002	-16.5223*
$Q_{(12)1}$	$g_{(12)1}$	0.0051584	0.003984	1.2948
$Q_{(13)1}$	$g_{(13)1}$	0.0000833	0.000001	8.3440*
Z_{22}	a_{22}	14.369455	1.6305641	8.8126*
Z'_{22}	b_{22}	-0.3299953	0.0376695	-8.7603
Z_{33}	a_{33}	0.0055701	0.0013782	4.0415

$S = 10$ $R^2 = 0.9970$ $Ra^2 = 0.9865$

$A_0 = 16.0861$ $t_2 = 4.303$

4.2.15 Statistical analysis of the chosen forecasting models under Variety 15

A total of six models were selected under this variety, namely two from Season II, one from Season III and three from Season IV.

a. Season II

1. $S2M5.V_{15}$

This forecasting model belonged to the category of square root models, particularly the model five as developed in Chapter III.

Z_{23}', Z_{33}' and $Q_{(23)2}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 95. The coefficients of all the variables were found to be significant at 5% level of significance. However the use of this model for the purpose of predicting yield prior to harvest could be ascertained only after evaluating its performance with other criteria measures.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 659.2601 + 41.303944 Z_{23}' - 135.51888 Z_{33}' + 8.525465 Q_{(23)2}$$

2. $S2M6.V_{15}$

This forecasting model belonged to the square root model category, namely the model six as developed in Chapter III.

Z'_{33}, $Q_{(12)1}$, $Q_{(13)2}$, $Q_{(23)1}$, $Q_{(34)1}$ and $Q_{(34)2}$ were the six predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 96. 95.46% of the total variance from the mean in yield response could be accounted for by the predictor variables fitted in the final crop forecasting model. However the use of this model for the purpose of predicting yield prior to harvest, depends on its performance with other criteria measures.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 62.209 - 0.3986638\, Z'_{33} - 0.0826592\, Q_{(12)1} + 0.0004411\, Q_{(13)2} + 0.0001511\, Q_{(23)1} + 0.0001826\, Q_{(34)1} + 0.0040366\, Q_{(34)2}$$

b. Season III

1. $S3M4.V_{15}$

This forecasting model belonged to the category of square root models, particularly the model four as developed in Chapter III.

Z_{33}, $Q_{(13)2}$, $Q_{(14)0}$ and $Q_{(24)0}$ were the four predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 97. The coefficients of all the variables except that of $Q_{(14)0}$ were found to be significant at 5% level of significance. The adequacy and fit of the model was satisfactory, however its use for the purpose of predicting yield prior to harvest could not be assessed until its performance with other criteria measures were studied.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 31.925 + 0.1123695\ Z_{33} - 0.047366\ Q_{(13)2} - 0.1446502\ Q_{(14)0} + 0.2193457\ Q_{(24)0}$$

c. Season IV

1. SAM1.V$_{15}$

This forecasting model belonged to the square model category, namely the model one as developed in Chapter III.

Z_{42}, Z_{31} and $Q_{(14)1}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 98. The coefficients of all the variables except that of Z_{42} were found to be significant at 5% level of significance. The adequacy and fit of the model was satisfactory, however its use for the purpose of predicting yield prior to harvest could not be assessed until its performance with other criteria measures were studied.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 0.5254 + 0.00155186\, Z_{42} + 0.000038\, Z_{31}' + 0.0001022\, Q_{(14)1}$$

2. $S4M3.V_{15}$

This forecasting model belonged to the category of square models, namely the model three as developed in Chapter III.

$Q_{(34)2}$ and $Q_{(23)1}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 99. The coefficients of both the variables were significant at 5% level of significance. The adequacy and fit of the model was satisfactory and it could be used for the purpose of predicting yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = -0.1185 + 0.0929616\, Q_{(34)2} + 0.0002326\, Q_{(23)1}$$

3. $S4M6.V_{15}$

This forecasting model belonged to the square root model category namely the model six as developed in Chapter III.

$Q_{(23)1}$, $Q_{(34)1}$ and $Q_{(34)2}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 100. The coefficients of the variable $Q_{(34)1}$ was significant at 5% level of significance. The adequacy and fit of the model was highly satisfactory and it could be used for the purpose of predicting yield prior to harvest.

The final form of the crop forecasting model developed through step up regression technique was

$$Y = 0.1010 + 1.1627951\, Q_{(34)2} + 0.0434454\, Q_{(23)1} - 0.4330296\, Q_{(34)1}$$

Table. 95 Step-up regression analysis of the crop forecasting model S2M5.V_{15}

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(23)2}$	$g_{(23)2}$	8.525465	3.218744	2.6487*
Z'_{33}	b_{33}	-135.51888	46.684288	-2.9029
Z'_{23}	b_{23}	-41.303944	15.472308	-2.6695

$S = 10$ $R^2 = 0.7325$ $Ra^2 = 0.5987$

$A_0 = 659.2601$ $t_6 = 2.447$

Table. 96 Step-up regression analysis of the crop forecasting model S2M6.V_{15}

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.0001826	0.0001542	1.1846
$Q_{(23)1}$	$g_{(23)1}$	0.0001511	0.0000972	1.5535
$Q_{(13)2}$	$g_{(13)2}$	0.0004411	0.0002642	-1.6696
$Q_{(34)2}$	$g_{(34)2}$	0.0040366	0.0018067	2.2343
Z'_{33}	b_{33}	0.3986638	0.1346789	-2.9601
$Q_{(12)1}$	$g_{(12)1}$	0.0826592	0.0218832	-3.7773*

$S = 10$ $R^2 = 0.9546$ $Ra^2 = 0.8638$

$A_0 = 62.209$ $t_3 = 3.182$

Table. 97 Step-up regression analysis of the crop forecasting model $S3M4.V_{15}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(13)2}$	$g_{(13)2}$	-0.047366	0.0150664	-3.1438*
Z_{33}	a_{33}	0.11236851	0.0417177	2.6935*
$Q_{(24)0}$	$g_{(24)0}$	0.2193457	0.0740289	2.9630*
$Q_{(14)0}$	$g_{(14)0}$	-0.1446502	0.0897181	-1.6123*

$S = 10$ $R^2 = 0.8175$ $Ra^2 = 0.6715$

$A_0 = 31.825$ $t_5 = 2.571$

Table. 98 Step-up regression analysis of the crop forecasting model $S4M1.V_{15}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{31}	b_{31}	0.0000380	0.0000155	2.4498*
$Q_{(14)1}$	$g_{(14)1}$	0.000102197	0.0000239	4.2703*
Z_{42}	a_{42}	0.00155186	0.0006852	2.2649

$S = 10$ $R^2 = 0.8544$ $Ra^2 = 0.8128$

$A_0 = 0.5254$ $t_6 = 2.447$

Table. 99 Step-up regression analysis of the crop forecasting model $S4M3.V_{15}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$g_{(34)2}$	0.0929616	0.0137602	6.7558*
$Q_{(23)1}$	$g_{(23)1}$	0.0002326	0.0000889	2.6176*

$S = 10$ $R^2 = 0.9239$ $Ra_2 = 0.9022$

$A_0 = -0.1185$ $t_7 = 2.365$

Table. 100 Step-up regression analysis of the crop forecasting model $S4M6.V_{15}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)2}$	$\varepsilon_{(34)2}$	1.1627951	0.3239507	3.5894*
$Q_{(23)1}$	$\varepsilon_{(23)1}$	0.0434454	0.0848416	5.1208*
$Q_{(34)1}$	$\varepsilon_{(34)1}$	-0.4330296	0.2950590	-1.4676

$S = 10$ $R^2 = 0.9709$ $Ra_2 = 0.9564$

$A_0 = -0.1010$ $t_6 = 2.447$

4.2.16 Statistical analysis of the chosen forecasting models under Variety 16.

A total of twelve models were selected under this variety. They were two models each from Season I and Season II and four models each from Season III and Season IV.

a. Season I

1. $S1M1.V_{16}$

This forecasting model belonged to the category of square models. particularly the model one as developed in Chapter III.

$Q_{(34)0}$ was the only predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 101. The coefficient of the variable was found to be significant at 5% level of significance. However the use of this model for the purpose of predicting yield prior to harvest could be judged based on its performance with other criteria measures.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 2.5418 + 0.0114386\ Q_{(34)0}$$

2. S1M2.V_{16}

This forecasting model belonged to the square model catgeory, namely the model two as developed in Chapter III.

$Q_{(34)0}$ was the only predictor variables included in the final crop forecasting model. from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 102. The coefficient of this variable was found to be significant at 5% level of significance. However the use of this model for the purpose of predicting yield prior to harvest could be ascertained on the basis of its performance with other criteria measures.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 2.5418 + 0.0343159\ Q_{(34)0}$$

b. Season II

1. S2M3.V_{16}

This forecasting model belonged to the category of square models, namely the model three as developed in Chapter III.

The four predictor variables included in the final crop forecasting model. from the nine preliminary selected variables were Z_{21}, Z_{22}, Z_{23}, and $Q_{(14)2}$. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 103. The coefficients of all the variables were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be satisfactory and hence it could be used for the purpose of predicting yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 2.5894 - 0.2004476\, Z_{21} + 0.1750551\, Z_{22} + 0.0006906\, Z_{23}' + 0.0356199\, Q_{(14)2}$$

2. $S2M6.V_{16}$

This forecasting model belonged to the category of square root models, namely model six as developed in Chapter III.

Z_{22}, Z_{23}, Z_{21}', Z_{33}', $Q_{(14)1}$ and $Q_{(14)2}$ were the six predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 104. The coefficients of all the variables except those of Z_{23} and Z_{33}' were found to be significant at 5% level of significance. The adequacy and fit of the model was highly satisfactory and this model could be used for the purpose of predicting yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 9.0578 + 0.1633814\, Z_{22} + 0.0002668\, Z_{23} - 1.8664008\, Z'_{21} - 0.2549532\, Z'_{33} - 0.1296078\, Q_{(14)1} + 0.1301011\, Q_{(14)2}$$

c. Season III

1. $S3M1.V_{16}$

This forecasting model belonged to the category of square models, namely the model one as developed in Chapter III.

Z_{22}, Z_{23} and $Q_{(24)1}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 105. The coefficients of all the variables except that of Z_{23} were found to be significant at 5% level of significance. The adequacy and fit of the model was highly satisfactory and this model could be used for the purpose of predicting yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 40.605 + 0.3410815\, Z_{22} - 0.0177324\, Z_{23} + 0.0048002\, Q_{(24)1}$$

2. $S3M3.V_{16}$

This forecasting model belonged to the square model category, particularly the model three as developed in Chapter III.

Z_{12}, Z_{12}', $Q_{(24)1}$ and $Q_{(24)2}$ were the four predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 106. The coefficients of all the variables were found to be significant at 5% level of significance. The adequacy and fit of the model was found to be highly satisfactory and could be used for the purpose of predicting yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 23.53803 + 13.427034\ Z_{12} - 0.1874177\ Z_{12}' \\ 0.2968039\ Q_{(24)1} + 0.3021403\ Q_{(24)2}$$

3. $S3M4.V_{16}$

This forecasting model belonged to the square root model category, namely model four as developed in Chapter III.

Z_{22}, Z_{23}', Z_{41}, Z_{42} and Z_{23}' were the five predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 107. The coefficients of all the variables except those of variables Z_{22} and Z_{41}' were found to be significant at 5% level of significance. The adequacy and fit of the model was highly satisfactory and this model could be used for the purpose of predicting yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 49.8485 + 0.1914509\, Z_{22} - 38.511905\, Z_{23} - 1.9823019\, Z_{41} + 2.1322774\, Z_{42} + 27.341916\, Z_{33}'$$

4. $S3M5.V_{16}$

This forecasting model belonged to the square root model category, particularly the model five as developed in Chapter III.

Z_{23}' and Z_{42} were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 108. The coefficients of both the variables were significant at 5% level of significance. The adequacy and fit of the model was satisfactory but its use for the purpose of predicting yield prior to harvest could be decided on the basis of its response with other criteria measures.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 2.0475 + 0.5344164\ Z_{42} + 19.52834\ Z_{23}'$$

d. Season IV

1. $S4M2.V_{16}$

This forecasting model belonged to the square model category, namely the model two as developed in Chapter III.

$Q_{(14)0}$ was the only predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table . 109. The coefficient of this variable was found to be significant at 5% level of significance. However the use of this model for the purpose of predicting yield prior to harvest could be ascertained on the basis of its performance with other criteria measures.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 4.8221 + 0.0409569\ Q_{(14)0}$$

2. $S4M3.V_{16}$

This forecasting model belonged to the category of square models, namely the model three as developed in Chapter III.

Z_{43}, $Q_{(34)0}$ and $Q_{(34)1}$ were the three predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 110. The coefficients of all these variables were found to be significant at 5% level of significance. The adequacy and fit of the model was highly satisfactory and this model could be used for the purpose of predicting yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 1.6739 + 0.4733316\ Z_{43} + 0.0636661\ Q_{(34)0}$$
$$0.0079508\ Q_{(34)1}$$

3. $S4M5.V_{16}$

This forecasting model belonged to the square root model category, particularly the model five as developed in Chapter III.

Z_{42}, $Q_{(14)0}$, $Q_{(34)1}$ and $Q_{(34)2}$ were the four predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 111. The adequacy and fit of the model was found to be satisfactory but its use in the field of predicting yield could be comprehended on the basis of its performance with other criteria measures.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 21.11[illegible]33 \;\; 2.6381905\, Z_{42} + 2.6739556\, Q_{(14)0}$$
$$+ \; [illegible]\, Q_{(34)1} \;\; 0.0061804\, Q_{(34)2}$$

R [illegible]

This forecasting model belonged to the category of square root models, particularly the model six as developed in Chapter III.

Z_{12} and $Q_{(34)0}$ were the two predictor variables included in the final crop forecasting model, from the nine preliminary selected variables. The estimated regression coefficients of these variables along with their standard error and computed t values were presented in Table. 112. The coefficients of both the variables were significant at 5% level of significance. The adequacy and fit of the model was highly satisfactory and could be used for the purpose of predicting yield prior to harvest.

The final form of crop forecasting model developed through step up regression technique was

$$Y = 19.8943 + 0.6613175 Z_{12}' + 3.8774533 Q_{(34)0}$$

Table. 101 Step-up regression analysis of the crop forecasting model $S1M1.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	0.0114386	0.0036935	3.0970*

$S = 10$ $R^2 = 0.5452$ $Ra_2 = 0.4884$

$A_0 = 2.5418$ $t_{5\%} = 2.262$

Table. 102 Step-up regression analysis of the crop forecasting model $S1M2.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	0.0343159	0.0110805	3.0970*

$S = 10$ $R^2 = 0.5452$ $Ra_2 = 0.4884$

$A_0 = 2.5418$ $t_8 = 2.306$

Table. 103 Step-up regression analysis of the crop forecasting model $S2M3.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{23}	b_{23}	0.0006906	0.0001861	3.7112*
$Q_{(14)2}$	$g_{(14)2}$	0.0356199	0.0092960	3.8317*
Z_{22}	a_{22}	0.17505516	0.0482413	3.6287*
Z_{21}	a_{21}	-0.2004476	0.0502	-3.9930*

$S = 10$ $R^2 = 0.8982$ $Ra^2 = 0.8167$

$A_0 = 2.5894$ $t_5 = 2.571$

Table. 104 Step-up regression analysis of the crop forecasting model $S2M6.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(14)2}$	$g_{(14)2}$	0.1301011	0.0309473	4.2040*
Z_{22}	a_{22}	0.1633814	0.0233316	7.0026*
Z_{23}	a_{23}	0.0002668	0.0046112	0.0579
$Q_{(14)1}$	$g_{(14)1}$	-0.1296078	0.0331284	-3.9123*
Z'_{33}	b_{33}	-0.2549532	0.0660151	-3.8620
Z'_{21}	b_{21}	-1.8664008	0.2803509	-6.6574

$S = 10$ $R^2 = 0.9864$ $Ra^2 = 0.9694$

$A_0 = 9.0578$ $t_3 = 3.183$

Table. 105 Step-up regression analysis of the crop forecasting model $S3M1.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z_{23}	a_{23}	-0.0177324	0.0138576	-1.2796
$Q_{(24)1}$	$g_{(24)1}$	0.0048002	0.0011402	4.2099*
Z_{22}	a_{22}	0.3410815	0.0897991	3.7983

$S = 10$ $R^2 = 0.8422$ $Ra^2 = 0.7633$

$A_0 = 40.605$ $t_6 = 2.447$

Table. 106 Step-up regression analysis of the crop forecasting model $S3M3.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{12}	b_{12}	-0.1874177	0.0689026	-2.8014*
Z_{12}	a_{12}	13.427034	4.3249421	3.1046*
$Q_{(24)1}$	$g_{(24)1}$	-0.2968039	0.112071	-2.6484*
$Q_{(24)2}$	$g_{(24)2}$	0.3021403	0.1018487	2.9666*

$S = 10$ $R^2 = 0.9243$ $Ra^2 = 0.8637$

$A_0 = 23.53803$ $t_5 = 2.571$

Table. 107 Step-up regression analysis of the crop forecasting model $S3M4.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{23}	b_{23}	27.341916	8.1087007	3.3719*
$Q_{(24)2}$	$g_{(24)2}$	0.3021403	0.1018487	2.9666*
Z_{23}	a_{23}	-38.511905	11.878727	-3.2421*
Z_{22}	a_{22}	0.1914509	0.1050056	1.8232
Z_{41}	a_{41}	-1.9823019	0.9531079	-2.0798
Z_{42}	a_{42}	2.1322774	0.7812640	2.7293

$S = 10$ $R^2 = 0.9616$ $Ra^2 = 0.9136$

$A_0 = 49.8485$ $t_4 = 2.776$

Table. 108 Step-up regression analysis of the crop forecasting model $S3M5.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
Z'_{23}	b_{23}	19.528345	4.8250975	4.0472*
Z_{42}	a_{42}	0.5344164	0.1619209	3.3005*

$S = 10$ $R^2 = 0.7864$ $Ra^2 = 0.7253$

$A_0 = 2.0475$ $t_7 = 2.365$

Table. 109 Step-up regression analysis of the crop forecasting model $S4M2.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(14)0}$	$g_{(14)0}$	0.0409569	0.0145377	2.8173*

S = 10 R^2 = 0.4980 Ra^2 = 0.4353

A_0 = 4.8221 t_8 = 2.306

Table. 110 Step-up regression analysis of the crop forecasting model $S4M3.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	REGRESSSION ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	0.0636661	0.0085808	7.4196*
$Q_{(34)1}$	$g_{(34)1}$	-0.0079508	0.0030994	-2.5653*
Z_{43}	a_{43}	0.4733316	0.1611908	2.9365*

S = 10 R^2 = 0.9555 Ra^2 = 0.9332

A_0 = 1.6739 t_6 = 2.447

Table. 111 Step-up regression analysis of the crop forecasting model $S4M5.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)1}$	$g_{(34)1}$	0.7491083	0.1777755	4.2138*
$Q_{(34)2}$	$g_{(34)2}$	-0.0061804	0.0029185	-2.1176
$Q_{(14)0}$	$g_{(14)0}$	2.6739556	1.0814044	2.4727
Z_{42}	a_{42}	-2.6381905	1.2373784	-2.1321

$S = 10$ $R^2 = 0.9084$ $Ra^2 = 0.8351$

$A_0 = 24.1073$ $t_5 = 2.571$

Table. 112 Step-up regression analysis of the crop forecasting model $S4M6.V_{16}$

VARIABLE SELECTED	REGRESSSION COEFF	ESTIMATE	STANDARD ERROR	COMPUTED t VALUE
$Q_{(34)0}$	$g_{(34)0}$	3.8774533	1.0315995	3.7587*
Z'_{12}	b_{12}	0.6613175	0.1279257	5.1695*

$S = 10$ $R^2 = 0.9510$ $Ra^2 = 0.8953$

$A_0 = 19.8943$ $t_7 = 2.365$

4.3 Comparative study of efficience, adequacy and performance of the crop forecasting model on the basis of criteria functions.

From the crop forecasting models mentioned in the previous sections, the 'best' most efficient, adequate and promising crop forecastin models which could serve the purpose of predicting the cashew crop yield prior to harvest were selected on the basis of the criteria functions as discussed in Chapter III. The criteria models employed in this study were

1. Mean Square Error or Residual Mean Square (RMS)
2. Squared Multiple Correlation Coefficients (R^2)
3. Adjusted R^2 (Ra^2)
4. Total Prediction Variance (Jp)
5. Prediction Mean Square Error (MSEF)
6. Average Estimated Variance (AEV)
7. Amemiya Prediction Criterion (APC)
8. Akaike Intimatio Criterion (AIC)

The criteria measures for all the 112 crop forecasting models were evaluated and categorised variety wise.

DISCUSSION

DISCUSSION

5.1 Introduction

In the present investigation attempts were made to :

1. develop a suitable and reliable statistical methodology for the preharvest forecast of cashew crop yield by constructing different emperical statistical crop weather model adopting original and generated weather variables as predictor variables.

2. perform a comparative study of relative efficiency, adequacy and peformance of each of these crop forecasting models evolved and to select the 'best' most promising and plausible crop forecasting models for the purpose of future use in predicting the crop yield reliably in advance of harvest.

With these objectives in mind, a total of 112 crop forecasting models were constructed under the Season I, Season II, Season III and Season IV. The two general forecasting models adopted for the generation of the predictor variable were the square model and the square root models.

A total of 6 forecasting models were developed giving different weights to the weather effects on the crop yields. These 6 forecasting models were developed for each of the 16 varieties of cashew, pertaining to each of the 4 seasons. Among the 42 generated predictor variables for each of the models, 9 relevant variables were selected on the basis of its correlation with yield and a further selection among these 9 variables were made by adopting the technique of step up regression. Those models obtained with significant F value were chosen for further statistical analysis.

Eight criteria functions were calculated for each of the forecasting models as illustrated in Table 113. Based on these criteria functions the 'best' most promising and plausible forecasting models for each variety for the suitable season could be selected.

1. Variety 1 (BLA-139-1)

This variety originating from the Cahsew Research Station, Anakkayam, Kerala, has 6 models to its credit ie 4 belonging to season I and one each from season II & season IV. Among models in season I, the model $S1M2.V_1$ was noticed to have the highest R^2 and Ra^2 value, along with the lowest RMS, APC and AIC values. Even the Jr, MSEP and AEV registered low values, if not the lowest. Therefore of the 4 models at hand in Season I, $S1M2.V_1$, was found to be the representative of the whole lot.

On season wise comparison it was again noticed that the model $S1M2.V_1$ registered the highest R^2 and Ra^2 value. Therefore the best and most promising forecasting model for the purpose of future use in predicting the crop yield reliably in advance of harvest for variety 1 was the model $S1M2.V_1$. It was evident from this selection that the distribution and intensity of the meteorological variables in the months of December, January and February make a significant contribution to the yield. The predictor variables fitted using the square model 2 was found to be most appropriate for this variety.

2. Variety 2 (Ansur - 1).

A native of the Vengurla Research Center, Maharashtra, this variety had a total of 14 models attributed to it namely 3 models from Season I, 4 models from Season II, 4 models from Season III and 3 models from Season IV.

Among the models in Season I, $S1M5.V_2$ acknowledge the highest R^2 and Ra^2 values along with the lowest value for all the other 6 criteria function. In Season II the model $S2M1.V_2$ was found to satisfy the necessary condition. The model $S3M1.V_2$ in Season III was found adhere approximately to the criteria function specification. In Season IV, the model $S4M6.V_2$ was selected in accordance to the high R^2 and Ra^2 value and the low values of the remaining 6 criteria functions.

Comparison between seasons showed that the model $S4M6.V_2$ could be chosen as the best most promising and plausible forecasting model for the purpose of future use in predicting the crop yield reliably in advance of harvest. It was evident from this that the climatic conditions prevailing during the months of September, October, November, December, January and February have a significant influence on yield. Moreover the predictor variables constructed by adopting the square root model 6 was found to be very suitable for this variety.

3. Variety 3 (K-27-1)

This variety of cashew, originated at the Cashew Research Station, Anakkayan, had 10 models attributed to it namely 1 model from Season I, 3 models from Season III and 6 models from Season IV.

Among the 3 models in Season III, $S3M3.V_3$ was found to have the least value for RMS, Jr, MSEP, APC and AIC with a high value for R^2 and Ra^2. In Season IV, S4M3.V3 was the model found to satisfy the conditions specified by each of the 8 criteria functions.

Between season comparisons revealed that the model $S4M6.V_3$ could be unanimously selected as the best most promising forecasting model for the purpose of future use in predicting the crop yield in advance of harvest. regarding the variety - 3. Thus the climatic conditions prevailing from the month of September to February was found to have significant influence on yield.

4. Variety 4 (Sawantwadi)

This variety of the Vengurla Research Center, Maharashtra, has 9 models attributed to it. They were, 2 models from Season I, 4 models from Season II, 2 models from Season III and one model from Season IV.

Among the 2 models from Season I the model $S1M5.V_4$ was found to adhere to all the conditions specified by the criteria functions. In Season II the model found to satisfy these necessaties approximately was $S2M3.V_4$. A representative of the forecasting models in Season III was the model S3M1.V_4 which was found to satisfy the conditions of the criteria functions specified atleast approximately. In Season IV the selected forecasting model was S4M1.V_4.

Among these 4 forecasting models the best and most promising forecasting model for the purpose of future use in predicting the crop yield reliably in advance of harvest for the variety 4 was the model S1M5.V_4. It could be seen that the climatic conditions during the months of December, January and February were found to have a significant influence of yield. Also the predictor variables fitted using the square root model 5 was seen to be satisfactory for this variety.

5. Variety 5 (K-10-2)

This variety from the Cashew Research Station, Anakkayam, Kerala had 6 models selected under it - namely one model from Season I, one from Season II, one from Season III and three from Season IV.

Among the 3 models from Season IV the model S4M6.V_5 was found to satisfy the conditions specified by the criteria functions.

Season-wise comparison revealed that the model S3M3.V_5 was found to be the best most promising forecasting model for the purpose of future use in predicting the crop yield reliably in advance of harvest. In this variety, the rainfall in the months of Dec, Jan and Feb, and temperature and sunshine during the months of Sept, Oct, Nov had significant influence on yield. The predictor variables developed using the square model 3 was seen to be the best for this variety.

6. Variety 6 (T-56 of BLA)

This variety from the Bapatla Research Centre, Andhra Pradesh, has 6 models selected under it namely 3 models from Season II and 2 models from Season III and one from Season IV.

From the 3 models in Season II, the model $S2M4.V_6$ was found to have the highest R^2 & Ra^2 value along with the lowest value for all the other 6 criteria functions. In Season III the model $S3M2.V_6$ satisfied the conditions specified by criteria functions.

Between season comparison revealed that for variety 6, the 'best' most promising forecasting model for the purpose of future use in predicting the crop yield reliably in advance of harvest was the model $S2M4.V_6$. Thus for variety 6 the distribution and intensity of the meteorological variables during the months of Sept, Oct, Nov had significant influence on yield. For variety 6, the predictor variables generated by the square root model 4 was most appropriate.

7. Variety 7 (M6/1)

This variety originated from the Vridhachalam Research Centre, Tamil Nadu, has 3 forecasting model attributed to it namely one model from Season I, one model from Season II and one model from Season III.

Between season comparisons showed that the model $S3M1.V_7$ was the best most promising forecasting model for the purpose for future use in predicting the yield reliably in advance to harvest, for variety 7. Moreover the yield of this variety was influenced by the temperature and sunshine during the months of Sept, Oct, Nov and the rainfall during Dec, Jan, Feb. It was also noticed that the predictor variables generated using model 1 was suitable for this variety.

8. Variety 8 (T-40 of BLA)

This variety from the Bapatla Research station, Andhra Pradesh, has 6 model attributed to it namely, 2 models from Season II and 4 models from Season IV

Among the 2 models in Season II, the model $S2M4.V_8$ was found to have the highest R^2 and Ra^2 values along with the lowest value for the other 6 criteria measures. In Season IV, the model $S4M5.V_8$ was found to have the highest values for R^2 and Ra^2 and lowest value for the remaining 6 criteria functions.

Between these 2 seasons, the model $S4M5.V_8$ was chosen as the most promising forecasting model for the purpose of future use in predicting the crop yield reliably in advance of harvest. The predictor variables constructed using the square root model 5 was most appropriate for variety 8.

9. Variety 9 (M 10/4)

This variety, developed at the Vridhachalam Research Station, Tamil Nadu, has 11 models attributed to it, namely 2 models from Season I, 2 from Season II, 2 models from Season III 5 models from Season IV.

From the 2 models in Season I, the model $S1M4.V_9$ was selected as it adhered to the regulations desired by each of the 8 criteria functions, approximately. In Season II, the model $S2M4.V_9$ which satisfied all the necessary specified requirements. Season III was represented by the model $S3M3.V_9$ as it registered the highest R^2 & Ra^2 value along with the lowest value for all the other criteria functions. In Season IV the model $S4M6.V_9$ was seen to satisfy the necessary requirements.

Among these 4 models, the best most promising forecasting model for the purpose of future use in predicting the crop yield reliably in advance of harvest for this variety was $S4M6.V_9$. Thus for variety 9 the climatic conditions for the 6 month period, i.e. from September to February had significant influence on crop yield. The prediction variables generated through the square root, model 6 was appropriate for this variety.

10. Variety 10 (M 76/1)

Originated from the Vridhachalam Research Centre.Tamil Nadu, this variety has ten models attributed to it i.e. five models from season II,one model from season III and five models from season IV.

Among the five models from the Season II the model $S2M5.V_{10}$ was found to have the highest value for R^2 and Ra^2 , along with the lowest value for all the other criteria functions. From the five models in Season IV, model $S4M4.V_{10}$ was seen to adhere to all the necessary specifications.

Now comparing these three models it was seen that model $S4M4.V_{10}$ was the most promising and plausible forecasting model for the purpose of future use in predicting the crop yield in advance of harvest for this particular variety of cashew. The square root model 4 was proved to be the most appropiate model for generating the predictor variables for this variety. Evidently the climatic conditions prevailing during the six months i.e. from September to February had a significance influence on crop yield.

11. Variety 11 (T-1 of BLA).

This variety was introduced in the Madakkathara Cashew Research Station from the Baptala Research Centre, Andhra Pradesh. Unfortunately this variety has not yielded any significant forcasting model in any of the 6 models pertainiung to the 4 seasons. The reason for this may be due to the variation in climatic conditions. This variety being essentially a native of Andhra Pradesh, it flourishes under home conditions. The change in climatic conditions must have had a negative influence on this high yielding variety which resulted in the present situation.

12. Variety - 12 (T - 273 of BLA).

This variety, introduced in Madakkathara Cashew Research Station from the Baptala Research Centre, Andhra Pradesh; had three models attributed to it namely two models from Season II and one model from Season III

Among the two models in Season II the model $S2M2.V_{12}$ satisfied all the necessary specifications of the criteria functions.

Between the models of the two seasons, the model $S2M2.V_{12}$ was found to be the most promising and plausible forecasting model for the purpose of future use in predicting crop yield reliably in advance of harvest. The predictor variables generated using the square model 2 was found appropiate for the variety 12. Also the months of September, October and November was seen to have significance influence on crop yield with respect to this variety.

13. Variety 13 (H-4-7).

This variety, introduced in Madakkathara Cashew Research Station from Anakkayam Research Centre, Kerala; has six models attributed to it. They were two models from Season I, one model from Season II, two models from Season III and three models from Season IV.

Among the two models from Season I the model $S1M5.V_{13}$ was found to have the highest R^2 and Ra^2 values and lowest values for the other six criteria functions. In Season III, the models $S3M1.V_{13}$ satisfied the necessary requirements as specified by the criteria functions. In Season IV the model $S4M4.V_{13}$ was also selected.

On comparing the models between the four seasons, the model $S1M5.V_{13}$ was the most promising and plausible forecasting model for the purpose of future use in predicting the crop yield prior to harvest. It was understood that the months of December, January and February were found to have significant influence on crop yield. The predictor variables generated using the square root model 5 was appropiate for this variety.

14. Variety 14 (Vengula - 37 - 3).

This variety, introduced in Madakkathara Cashew Research Station form the Vengurla Research Centre, Maharasthra; has three models attributed to it i.e. one model from Season I, one form Season II and one from Season III.

Among the three models, the best most promising and plausible forecasting model for the purpose of future use in predicting the crop yield in advance of harvest was S3M3.V_{14} . From this model it was obvious that the rainfall during the months of December, January, Fenruary while temperature and sunshine during the months of September, October, November had significant influence on crop yield. The predictor variable generated using the square model 3 was appropiate for this variety.

15. Variety 15 (BLA - 256/1).

A native of Baptala Research Station, Andhra Pradesh this variety was attributed five models i.e. two models from Season II, two models from Season III and two models from Season IV.

Among the two models in Season II, the model S2M6.V_{15} had the highest R^2 and Ra^2 values while the values of the other six criteria functions were the lowest. In Season III the model S3M4.V_{15} was satifactory according to the specifiction of the criteria functions. In Season IV, the model S4M6.V_{15} was found in accordance to the necessary requisits of the criteria functions.

Comparing the models between the three seasons, the model S4M6.V_{15} was found the most promising and plausible forecasting model for the purpose of future use in predicting yield reliably prior to harvest. Thus for variety 15 the months from September to October had significant influence on yield. Moreover the predictor variables generated using the square root model 6 was accurate with respect to variety 15.

16. Variety 16 (Vengula - 36 - 3).

A native of the Vengurla Research Centre, Maharashtra, this variety has twelve models attributed to it namely two models form Season I, two models from Season II, four models from Season III and four models from Season IV.

Among the two models in Season I, the model $S1M1.V_{16}$ was found to satify the necessary specification as prescribed by the criteria functions. In Season II the model $S2M6.V_{16}$ registered the highest R^2 and Ra^2 values along with the lowest value fot the other criteria functions. In Season III, the model $S3M4.V_{16}$ was chosen as the model representative of the season. The model $S4M3.V_{16}$ satified all the necessary requirements set up by the criteria functions.

The model chosen as the 'best' most promising and plausible forecasting model for the purpose of future use in predicting the crop yield in advance of harvest, among the four seasons was $S4M3.V_{16}$. Thus the climatic conditions prevailing during the six months i.e. form September to February were noted to have a significant influence on the crop yield of this particular variety. Further the predictor variables generated using the square model 3 was appropiate in relation to variety 16.

Since no investigations in the field of forecasting yield using crop forecasting models has been conducted in cashew crop. comparative studies between results obtained previously cannot be conducted. Now considering the results obtained in this study, it can be seen that the square root model, model 6 namely

$$Z_{ik} = \sum_{w=1}^{n} r_{iw}^{k}(1)\, X_{iw} \Big/ \sum_{w=1}^{n} r_{iw}^{k}(1)$$

$$Z'_{ik} = \sum_{w=1}^{n} r_{iw}^{k}(4)\, X_{iw}^{(1/2)} \Big/ \sum_{w=1}^{n} r_{iw}^{k}(4)$$

$$Q_{(ij)k} = \sum_{w=1}^{n} r_{(ij)w}^{k}(5)\, X_{iw}^{(1/2)} X_{jw}^{(1/2)} \Big/ \sum_{w=1}^{n} r_{(ij)w}^{k}(5), \quad i<j$$

where $r_{iw}(1)$, $r_{iw}(4)$ and $r_{(ij)w}(5)$ are the correlation coefficients of cashew crop yield Y with X_{iw}, $X_{iw}^{(1/2)}$ and $X_{iw}^{(1/2)}$ $X_{jw}^{(1/2)}$ $(i<j)$ respectively

was the model commonly effective for the varieties of cashew considered here namely Ansur - 1, K - 27 - 1, M 10/4 and BLA - 256/1. Thus it can be concluded that the square root model 6 can be adopted successfully for constructing the predictor variables to be incorporated in the final crop forecasting model for cashew, in general.

From the four seasons developed it can be seen that the six month season namely Season IV, proves to be the maximum effective in relating the influence of the meteorological parameters on yield and thus helping in fitting the appropriate crop forecasting model. The Table. 114 represents the correlation of yield response Y with each of the four meteorological parameters for all the six months. From this table it can be summarised that temperature and sunshine during the months of November and rainfall during the months of January are the main yield contributing factors.

5.2 Further suggestions and guidelines for the development of statistical crop weather models.

In this investigation, quadratic polynomials of degree 2 was taken for all the periods to approximate the linear, quadratic and interactive effect of the weather parameters on crop yield. In order to get a better and precise estimate of the weather effects on the crop, the degree of polynomial should be increased from m=2 to m=5 in line with the suggestion of Fisher (1924).

From the point of view of 'econometrics' the crop forecasting models developed in this investigation were actually 'multivariable finite distributed lag models' in all the seasons within the effective crop season. Some of the drawbacks encountered while using these models are that it is difficult to capture any long tailed effect of weather variables spread over the whole effective crop season by means of a simple second degree polynomial. To overcome this flaw it is highly recommended and suggested that the '<u>infinite distributed lag models</u>' should be used for future development in crop forecasting models because infinite distributed lag approach is more appropiate to the perennials. Some of the infinite distributed lag models recommended to be tried are

1. Geometric lag
2. Pascal lag
3. Gamma distribution lag
4. Geometric polynomial lag
5. Exponential lag
6. Revised Gamma lag

After developing the appropriate crop forecasting models through the above infinite distributed lag methods', selection of the variables and fitting of the model should be carried out through any of the following statistical technique.

1. Ridge regression.
2. Principal component regression
3. Stepwise regression using forward and downward selection procedure.
4. Latent root regression.
5. Weather index regression.

After fitting the crop forecasting models through the techniques mentioned above, all the criteria functions given in Chapter III are highly recomended . In selecting the best, most processing and plausible crop forecasting model. The other 2 criteria functons compatible with our prediction purposes are,

1. Prediction sum and squares (PRESS)
2. Mallows' Cr Statistic.

Finally, while looking at the practical application of this study it can be stated that the models generated here, help in formulating an estimate of the expected production of the crop well ahead of harvest. Hence these types of studies will help to estimate the total yield of cashew crops for future periods with a reasonable degree of reliability for the use in planning, storage facilities, export - import prices, processing policies and financial policies of the Government. Moreover these studies helps in observing the inter-relationship between yield and meteorological factors and undestanding the periods in the life cycle of the crop during which these factor (s) have profound influence on its growth. These informations if handed down to the cashew cultivators, prove to be helpful in planning the life span of the crop so that it thrives under optimum conditions.

Table. 113 Variety wise criteria measures for the significant crop forecasting models developed through step-up regression

VARIETY 1

MODEL	RMS	R^2	R_a^2	Jr	MSEP	AEV	APC	AIC
$S1M2.V_1$	0.2071	0.9899	0.9546	3.7278	2.0503	0.1657	0.3729	9.8459
$S2M3.V_1$	0.2563	0.6501	0.6063	3.0759	0.3625	0.5126	2.1531	9.8572
$S4M6.V_1$	0.1769	0.7239	0.6894	2.1233	0.2502	0.0354	1.6986	8.1753

VARIETY 2

MODEL	RMS	R^2	R_a^2	Jr	MSEP	AEV	APC	AIC
$S1M5.V_2$	0.1254	0.8305	0.7457	1.7554	0.2483	0.005	1.0532	5.1316
$S2M1.V_2$	0.1362	0.8157	0.7236	1.9075	0.2698	0.0545	1.1445	5.5579
$S3M1.V_2$	0.1635	0.8464	0.7236	2.4531	0.4048	0.0818	1.2265	6.5222
$S4M6.V_2$	0.0214	0.9905	0.9958	0.4066	0.1701	0.0193	0.0236	5.3668

VARIETY 3

MODEL	RMS	R^2	R_a^2	Jr	MSEP	AEV	APC	AIC
$S1M4.V_3$	0.4674	0.7157	0.6345	6.0760	0.7712	0.1402	4.2532	17.1651
$S3M3.V_3$	0.6004	0.6348	0.5305	7.8050	0.9906	0.1801	5.4636	18.5583
$S4M6.V_3$	0.0746	0.9755	0.9559	1.119	0.1846	0.0273	0.5595	8.5572

TABLE 4

MODEL	RMS	R^2	R_a^2	[illegible]	MSEP	AEV	APC	AIC
$S1M5.V_4$	0.2067	0.4753	[illegible]	[illegible]	0.3303	0.0047	0.3404	3.8965
$S2M3.V_4$	0.0451	0.8554	[illegible]	0.6771	0.1117	0.0226	0.3385	0.4375
$S3M1.V_4$	0.1913	0.6475	0.7261	2.8645	0.4735	0.0955	1.1478	5.9132
$S4M1.V_4$	0.1286	0.7435	0.6779	1.6712	0.2121	0.0386	1.1698	4.7744

VARIETY 5

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S1M6.V_5$	0.4362	0.8763	[illegible]	6.543	1.0796	0.2181	3.2716	17.5883
$S2M6.V_5$	0.4527	0.7434	[illegible]	5.8853	0.7470	0.1358	4.1197	17.3467
$S3M3.V_5$	0.1917	0.9217	0.8826	2.6840	0.3796	0.0767	1.6104	12.8861
$S4M6.V_5$	0.4291	0.6885	0.6496	5.1491	0.6068	0.1858	4.1193	16.6927

VARIETY 6

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S2M4.V_6$	0.0469	0.9936	0.9714	0.8442	0.4643	0.0375	0.1688	5.6525
$S3M2.V_6$	0.2027	0.6633	0.5671	2.6345	0.3344	0.0608	1.8441	8.0726
$S4M3.V_6$	0.1736	0.7116	0.6292	2.2570	0.2865	0.0521	1.5798	7.2005

VARIETY 7

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S1M1.V_7$	0.1722	0.5635	0.5000	2.0660	0.2435	0.0344	1.6528	6.4852
$S3M1.V_7$	0.1178	0.9252	0.8317	1.8856	0.3889	0.0707	0.7543	5.1398
$S4M3.V_7$	0.1307	0.6686	0.6212	1.5684	0.1848	0.0261	1.2548	4.6230

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S2M4.V_8$	0.1439	0.6527	0.5534	1.8712	0.2375	0.0432	1.3099	4.5102
$S4M5.V_8$	0.0552	0.9673	0.9265	0.8840	0.1823	0.0332	0.2652	-0.0722

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S1M4.V_{9}$	0.3331	0.8407	0.6164	5.3296	1.0992	0.1999	2.1319	10.4188
$S2M4.V_{9}$	0.1560	0.8322	0.7483	2.1833	0.3088	0.0624	1.3099	7.3627
$S3M3.V_{9}$	0.2143	0.7694	0.6541	3.0004	0.4243	0.0857	1.8003	8.9568
$S4M6.V_{9}$	0.0516	0.9244	0.9028	0.6708	0.0851	0.0155	0.4096	-0.1278

VARIETY 10

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S2M5.V_{10}$	0.0944	0.9699	0.9324	1.51	0.3114	0.0566	0.6040	8.6692
$S3M3.V_{10}$	0.2066	0.9756	0.9269	3.5128	1.0228	0.1446	0.6935	10.9320
$S4M4.V_{10}$	0.0675	0.9879	0.9637	1.1481	0.3343	0.0473	0.3444	8.9193

VARIETY 12

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S2M2.V_{12}$	0.0618	0.9132	0.8183	0.9888	0.2039	0.0371	0.3955	-1.8162
$S3M6.V_{12}$	0.4463	0.9731	0.9344	5.1084	0.7225	0.1460	3.0651	14.0792

MODEL	RMS	R^2	Ra^2	Jc	MSEP	AEV	APC	AIC
S1M5.V_{13}	0.0081	0.9367	0.8861	0.1213	0.02	0.004	0.6063	4.4163
S2M4.V_{13}	0.2350	0.6395	0.5365	3.0546	0.3877	0.0705	2.1383	9.2383
S3M1.V_{13}	0.1556	0.9229	0.8266	2.4888	0.5133	0.0933	0.9955	7.7188
S4M4.V_{13}	0.1399	0.8423	0.7635	1.9586	0.2770	0.656	1.1752	6.5737

VARIETY 14

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S2M6.V_{14}$	0.3707	0.8179	0.5403	5.9308	1.2232	0.2224	2.3723	10.5196
$S2M6.V_{14}$	0.2705	0.4654	0.4020	3.2463	0.3860	0.0541	2.5971	10.2404
$S3M3.V_{14}$	0.0245	0.9970	0.9865	0.4401	0.2421	0.0196	0.0879	5.1700

VARIETY 15

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S2M5.V_{15}$	0.4075	0.7325	0.5987	5.7055	0.8069	0.1630	3.4232	14.5923
$S2M6.V_{15}$	0.2767	0.9546	0.8638	4.7033	1.3695	0.1937	1.4110	13.5258
$S3M4.V_{15}$	0.4004	0.8175	0.6715	6.0057	0.9909	0.2002	3.0028	14.4381
$S4M1.V_{15}$	0.1896	0.8544	0.8128	2.4650	0.3129	0.0569	1.4790	9.1401
$S4M3.V_{15}$	0.0851	0.9239	0.9022	1.1067	0.1405	0.0255	0.7747	4.8568
$S4M6.V_{15}$	0.0443	0.9709	0.9564	0.6202	0.0877	0.0177	0.3722	2.4054

VARIETY 16

MODEL	RMS	R^2	Ra^2	Jr	MSEP	AEV	APC	AIC
$S1M1.V_{16}$	0.3310	0.5452	0.4884	3.9716	0.4681	0.0662	3.1773	12.8724
$S2M6.V_{16}$	0.7285	0.9864	0.9694	1.1656	0.2404	0.0437	0.2531	4.8384
$S3M4.V_{16}$	0.1118	0.9619	0.9136	1.788	0.3688	0.0671	0.7152	8.8406
$S4M3.V_{16}$	0.0576	0.9555	0.9332	0.8069	0.1141	0.0231	0.4841	3.2653

Table. 114 Correlation of Yield Response with each of the four meteorological parameters in Season IV (Six month period)

	Maximum Temperature						Minimum Temperature					
Variety	Sept	Oct	Nov	Dec	Jan	Feb	Sept	Oct	Nov	Dec	Jan	Feb
V 1	-0.5592	-0.1859	0.3585	0.2322	0.1469	-0.0687	-0.4128	-0.2460	-0.1374	-0.0047	-0.0002	0.298
V 2	-0.3995	-0.4304	0.4269	0.4885	0.3124	-0.0077	-0.1766	-0.4632	-0.3027	-0.3935	0.3674	0.510
V 3	-0.3581	-0.1713	0.3390	0.2821	0.1709	-0.4922	-0.0023	0.0027	-0.2466	-0.1464	0.0064	0.553
V 4	-0.4306	-0.0048	0.4687	0.2546	0.1202	-0.0053	-0.3128	-0.1213	-0.0076	0.0056	-0.0011	0.241
V 5	-0.0049	-0.3139	0.4876	0.5737	0.3547	0.1148	-0.0034	-0.4792	-0.0023	-0.5214	0.3316	0.5110
V 6	-0.6238	-0.2156	0.2232	0.0062	0.1489	-0.0003	-0.3111	-0.1028	-0.3223	-0.1676	-0.1018	0.0082
V 7	-0.7472	-0.0076	0.2159	0.0039	0.0042	-0.0087	-0.1596	0.1297	-0.2986	-0.0098	-0.0029	0.0085
V 8	-0.4731	-0.2927	-0.1214	-0.2397	-0.1952	-0.0081	-0.3798	0.0043	-0.4683	-0.3215	0.2120	-0.1129
V 9	-0.5966	-0.3337	0.2273	0.1105	0.1318	0.0074	-0.5031	-0.3266	-0.4952	-0.0077	0.1813	0.0049
V 10	-0.4880	-0.1482	0.2888	0.3736	0.1934	0.3438	-0.1565	-0.2030	-0.2012	-0.1024	0.3294	0.002
V 11	-0.2020	-0.0097	0.4713	0.2203	0.1311	0.0068	-0.2536	-0.1897	-0.1874	-0.2230	0.0099	0.1096
V 12	-0.3041	-0.3568	0.4043	0.3860	0.3625	0.1618	-0.2775	-0.4236	-0.3420	-0.3051	0.2947	0.3035
V 13	-0.0091	-0.008	0.3625	0.2118	0.1067	0.4200	-0.3052	-0.2757	-0.1356	-0.1922	0.2030	-0.1193
V 14	-0.2187	-0.3984	0.3047	0.3489	0.3063	0.1819	-0.2460	-0.4089	-0.3722	-0.3938	-0.3129	0.2657
V 15	-0.6801	-0.2965	0.2297	0.009	0.1625	-0.1767	-0.2861	-0.1231	-0.5062	-0.1269	0.0053	0.1668
V 16	-0.3174	-0.2842	0.5046	0.4246	0.3977	-0.4603	-0.0046	-0.2373	-0.2554	-0.1972	0.1656	0.7264

	Rainfall						Sunshine					
Variety	Sept	Oct	Nov	Dec	Jan	Feb	Sept	Oct	Nov	Dec	Jan	Feb
V 1	0.2181	-0.1286	-0.5481	0.5729	0.3795	0.1096	0.1823	0.0088	0.6498	0.1121	0.2992	0.40
V 2	0.3141	-0.0054	-0.6867	0.3080	0.5343	0.5800	0.1797	0.3200	0.6805	0.3125	0.2028	0.24
V 3	0.2352	-0.3036	-0.2483	0.4155	0.4291	0.5646	0.1270	0.3810	0.4833	0.2271	0.6066	0.569
V 4	0.1699	-0.0014	-0.4370	0.4502	0.3718	0.1257	0.1705	0.1668	0.5637	0.0012	0.3734	0.423
V 5	0.0468	0.4694	-0.4156	0.0074	0.1727	0.5069	0.1910	0.2479	0.5153	0.3798	0.0074	0.004
V 6	0.5455	0.0073	-0.4006	0.1293	0.6233	0.002	-0.2152	0.1086	0.4898	0.1108	0.3553	0.404
V 7	0.3490	-0.1076	-0.2510	0.2379	0.6968	0.1568	-0.0075	0.1876	0.3740	0.1441	0.4102	0.3997
V 8	0.3445	0.0083	-0.1149	-0.0217	0.7718	0.1173	-0.3911	-0.1871	-0.1397	0.1153	0.3268	0.3307
V 9	0.4114	-0.3042	-2.7292	0.4540	0.6876	0.1462	-0.0024	0.0035	0.4980	-0.0684	0.0766	0.2076
V 10	0.3757	-0.0091	-0.6480	0.2346	0.7106	0.0508	0.1620	0.2557	0.6650	0.1448	-0.0052	0.0026
V 11	0.1754	0.2037	-2.3836	0.1278	0.3734	0.2202	-0.001	0.1445	0.3105	0.2057	0.2333	0.2285
V 12	0.2556	0.1575	-0.5796	0.3205	0.4337	0.3358	0.0019	0.1465	0.5359	0.1238	0.0038	0.0075
V 13	0.0051	0.3226	-0.4164	0.0085	0.3282	0.0013	0.0017	-0.0018	0.2178	0.0079	-0.1379	0.1090
V 14	0.1923	0.2246	-0.4915	0.2298	0.4657	0.3875	-0.0027	0.0082	0.3997	0.1684	-0.0022	-0.0097
V 15	0.6313	-0.2971	-0.5555	0.2476	0.7738	0.2413	-0.1617	0.2361	0.5337	0.1617	0.3981	0.4592
V 16	0.2726	-0.1870	-0.4124	0.4631	0.2197	0.6365	0.1435	0.4274	0.6318	0.2168	0.5292	0.5155

SUMMARY

SUMMARY

The yield data of 16 varieties of cashew crop maintained at the Cashew Research Station, Madakkathara, Trichur and the meteorological data for the region of Madakkathara collected from the Meteorological Observatory, Vellanikara, Trichur, were utilised in the present study with the following objectives

1. To develop a suitable and reliable statistical methodology for the preharvest forecast of crop yields by constructing different empherical statistical crop weather models adopting original and generated weather variables as predictor variables.

2. To perform a comparative study of relative efficiency, adequacy and performance of each of these crop forecasting models evolved and to select the 'best', most promising and plausibile crop forecasting models for the purpose of future use in predicting the crop yield reliably in advance of harvest.

The data on the meteorological variables i.e maximum temperature in (^{o}C), minimum temperature in (^{o}C), rainfall in (cms) and sunshine hours were collected on a monthly basis. A total of 6 forecasting models were proposed which could be broadly classified into 2 categories. The former 3 models fall into the category of square models while the latter 3 models could be categorized as the square root models. Thus with three different weights given to the effect of weather variables, six different crop forecasting models were developed from the general square and square root models.

In the crop forecasting model, the average yield in kgs. of a particular variety in a given year was taken as the response variable. Now the effective crop season for those six models was a period of 6 months just prior to harvest. Different combinations of this 6 months were also taken into consideration to study its effects on crop. Further it was also noticed that rainfall during the months of December, January and February and temperature and sunshine during the months of September, October and November had significant influence on yield. Based on these informations, seasons were defined as follows

Season I	-	December, January, February
Season II	-	September, October, November
Season III	-	Rainfall from December, January, February Temperature and sunshine from September, October, November
Season IV	-	September, October, November, December, January, February

Thus under each season, 6 models were introduced for each of the 16 varieties of cashew crop. Second degree polynomials were used to approximate the linear, quadratic and interactive effects of weather variables. 42 predictor variables were obtained for each of the forecasting model. Simple correlation of these 42 predictor variables with yield were worked out and nine preliminary variables having maximum absolute correlation were selected.

The final crop forecasting model for the yield of cashew crop were fitted through stepwise regression technique based on the data for these 9 preliminary selected variables.

Comparative study of the relative efficiency, adequacy and performance of each of these forecasting models were evaluated by adopting certain criteria functions and assessing how each of the selected models responded to these functions. The criteria functions used in this study were residual mean square (RMS), squared multiple correlation (R^2), adjusted squared multiple correlation (Ra^2), total prediction variance (Jr), prediction mean square error (MSEP), average estamated variance (AEV), Amemiya prediction criterion (APC) and Akaike information criterion (AIC).

The crop forecasting model selected as the 'best' most promising & plausible crop forecasting model developed for the purpose of future use in predicting the yield of cashew crop in advance of harvest, for each the 16 varieties were as follows:

1. <u>Crop forecasting for variety 1</u> (SIM2. V1)

$$Y = 20.4684 + 0.0000295\, Z'_{31} + 0.3917404\, Z'_{42} + 0.1126352\, Z'_{43} + 0.1088218\, Q_{(13)0} - 0.1366307\, Q_{(23)0} - 1.0997231\, Q_{(24)1} + 0.7923317\, Q_{(24)2}$$

2. **Crop forecasting model for variety 2** (S4M6.V2)

$$Y = 62.0147 + 16.0107\, Z_{12} - 0.2450205\, Z'_{12} + 0.0452517\, Q_{(34)0}$$

3. **Crop forecasting model for variety 3** ($S4M6.V_3$)

$$Y = 23.6673 + 2.2881135\, Z'_{12} + 0.397293\, Q_{(23)0} - 0.1559021\, Q_{(23)1} + 1.3805265\, Q_{(34)0}$$

4. **Crop forecasting model for variety 4** ($S1M5.V_4$)

$$Y = -1.3590 + 0.3874032\, Z_{41} - 56.540889\, Z'_{31} + 11.337531\, Q_{(13)0} + 9.5409059\, Q_{(13)1} + 1.9382851\, Q_{(34)1} - 14.092514\, Q_{(23)1}$$

5. **Crop forecasting model for variety 5** ($S3M3.V_5$)

$$Y = 1.2983 + 0.012832\, Z'_{22} - 0.0000437\, Q_{(23)1} + 0.0004246\, Q_{(34)1}$$

6. **Crop forecasting model for variety 6** ($S2M4.V_6$)

$$Y = 2043.6768 + 14.545209\, Z_{22} + 0.0083411\, Z_{31} - 2.2541117\, Z_{43} - 152.8894\, Z'_{21} - 30.28649\, Z'_{23} + 6.3456912\, Z'_{43} + 0.8100659\, Q_{(14)2}$$

7. **Crop forecasting model for variety 7** ($S3M1.V_7$)

$$Y = 12.5055 + 0.0270884\, Z'_{42} - 0.0383669\, Q_{(14)0} + 0.0097768\, Q_{(14)1} + 0.0091349\, Q_{(14)2} + 0.0270884\, Q_{(24)1}$$

8. **Crop forecasting model for variety 8** ($S4M5.V_8$)

$$Y = 6.1334 - 3.9370093\, Z'_{33} - 7.3889775\, Q_{(13)1} + 7.1391158\, Q_{(23)1}$$

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FORECASTING MODELS FOR CROP YIELD IN CASHEW *(ANACARDIUM OCCIDENTALE L.)*

By

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ABSTRACT OF A THESIS

submitted in partial fulfilment of
the requirement for the degree

Master of Science (Agricultural Statistics)

Faculty of Agriculture
Kerala Agricultural University

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COLLEGE OF VETERINARY AND ANIMAL SCIENCES
Mannuthy - Trichur

1987

ABSTRACT

The study conducted for the region of Madakkathara with the following views and objectives i.e.

1. to develop a suitable and reliable statistical methodology for the pre harvest forecast of cashew crop yields by constructing empherical statistical crop weather models adopting original and generated weather variables as predictor variables.

2. to perform a comparative study of relative efficiency, adequacy and performance of each of these forecasting models evolved and to select the 'best' most promising and plausible crop forecasting models for the purpose of future use in predicting the crop yield reliably in advance of harvest.

utilised the yield data of 16 varieties of cashew crop maintained at the Cashew Research Station, Madakkathara, Trichur, along with the monthly meteorological data pertaining to variables - maximum temperature (^{o}C), minimum temperature (^{o}C), rainfall (cms) and sunshine hours for the region Madakkathara from the Meteorological Observatory, Vellanikara, Trichur.

Six forecasting model were developed by attributing three different weights to the general square and square root forecasting models. With an effective crop season of 6 months, four seasons were developed by taking different combinations of this six month period. Thus for each variety of cashew in a particular season, 6 forecasting models were developed, using the generated weather predictor variables.

The final crop forecasting models were constructed using the technique of stepwise regression. A comparative study of adequacy, predictive efficiency and performance of these crop forecasting models were carried out and the best most promising and plausible crop forecasting models for each variety of cashew was selected on the basis of its performance with criteria function ie residual mean square (RMS), squared multiple correlation coefficient (R^2) adjusted R^2 (Ra^2), total prediction variance (Jr), prediction mean square error (MSEP), average estimated variance (AEV), Amemiya prediction criterion (APC) and Akaike Information criterion (AIC).

From the study it was seen that the best forecasting model for the purpose of predicting yield in advance of harvest for the varieties 1, 5, 7, 12, 14, & 16 were of the square model type and that of the remaining ten varieties were of the square root model type. Finally it was concluded that the square root model 6 could be adopted successfully for constructing the predictor variables tobe included in the final crop forecasting model for cashew in general. Correlation of meteorological parameters with yield revealed that sunshine and temperature in November while rainfall in January were the trend setting factors of production.