

**A comparative study of the estimators  
obtained from weighted means of mean per  
unit estimator and ratio / product  
estimators**



**THESIS**  
*Submitted to the*

**Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur**

**In partial fulfilment of the requirements for  
The Degree of**

**MASTER OF SCIENCE**

*In*

**AGRICULTURE**

**(Statistics)**

*By*

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Jabalpur (M.P.)**

**2007**

Dedicated to  
My Beloved Parents

Shri R.S.Rajput  
&  
Smt.Urmila Rajput

## CERTIFICATE I

This is to certify that the thesis entitled " **A comparative study of the estimators obtained from weighted means of mean per unit estimator and ratio / product estimators** " submitted in partial fulfilment of the requirements for the degree of **Master of Science in Agricultural Statistics** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. Umesh Singh** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and Director of Instruction.

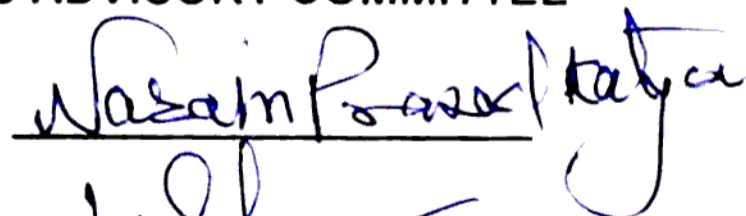
No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published. All the assistance and help received during the course of the investigation has been acknowledged by him.

  
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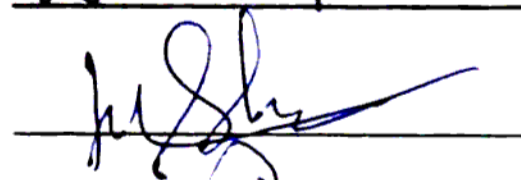
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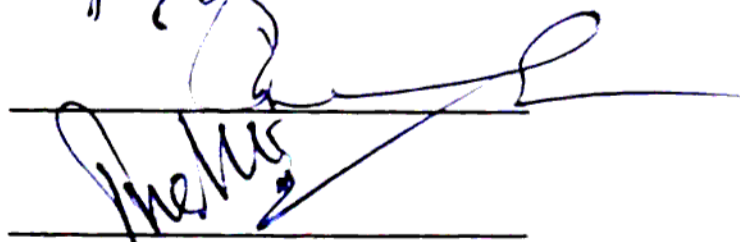
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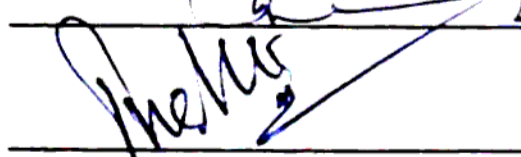
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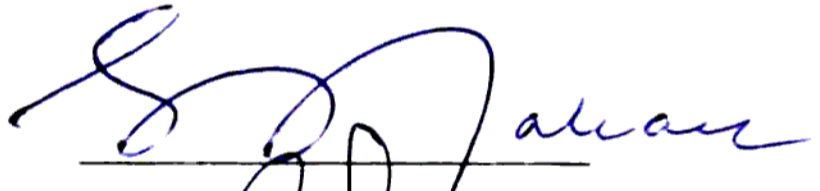
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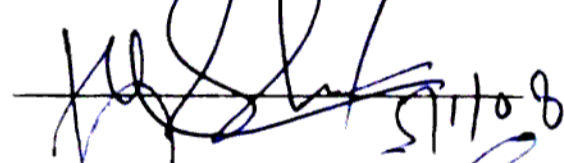
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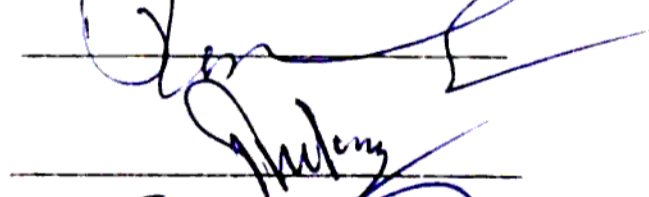
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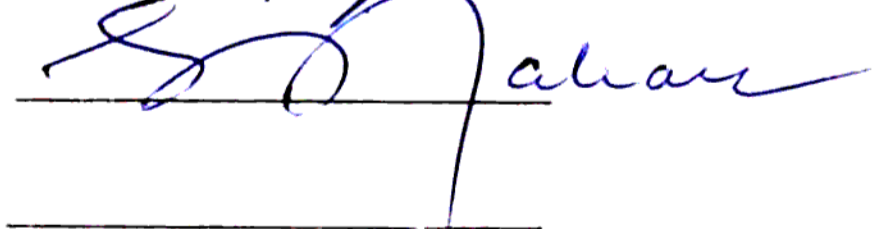
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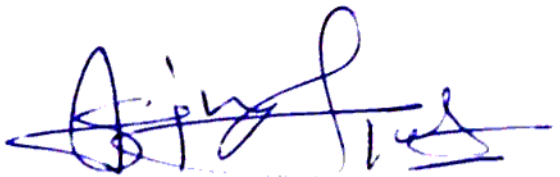
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*Place: Jabalpur*

*Date:*



*(Umesh Singh)*

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## LIST OF SYMBOLS

| Symbols/ Abbreviation | Stand for                              |
|-----------------------|--|
| +                     | Plus                                   |
| -                     | Minus                                  |
| ±                     | Plus minus                             |
| ≠                     | Is not equal to                        |
| >                     | More than                              |
| <                     | Less than                              |
| ≥                     | Equal or more than                     |
| ≤                     | Equal or less than                     |
| √                     | Square root                            |
| %                     | Percentage                             |
| X <sup>2</sup>        | Squared                                |
| Σ                     | Summation                              |
| “t” test              | Student t test                         |
| d.f.                  | Degree of freedom                      |
| CV                    | Coefficient of variation               |
| Kg.                   | Kilogram                               |
| ha.                   | Hectare                                |
| w                     | Weight                                 |
| W <sub>0</sub>        | Optimum weight                         |
| MSE                   | Mean square error                      |
| N                     | Total no. of observation               |
| n                     | No. of observation in sample           |
| $\bar{x}$             | Sample mean of auxiliary character X   |
| $\bar{y}$             | Sample mean of character under study Y |
| $\bar{y}_R$           | Ratio estimator                        |
| $\bar{y}_P$           | Product estimator                      |

|                |   |
|----------------|---|
| $\bar{y}_{AR}$ | Weighted arithmetic mean of mean per unit estimator and ratio estimator   |
| $\bar{y}_{AP}$ | Weighted arithmetic mean of mean per unit estimator and product estimator |
| $\bar{y}_{GR}$ | Weighted geometric mean of mean per unit estimator and ratio estimator    |
| $\bar{y}_{GP}$ | Weighted geometric mean of mean per unit estimator and product estimator  |
| $\bar{y}_{HR}$ | Weighted harmonic mean of mean per unit estimator and ratio estimator     |
| $\bar{y}_{HP}$ | Weighted harmonic mean of mean per unit estimator and product estimator   |
| $\rho$         | Correlation coefficient   |
| $m$            | Constant  |
| $b$            | Small positive constant   |
| $C_y$          | Coefficient of variation of Y   |
| $C_x$          | Coefficient of variation of X   |

CHAPTER – I  
**INTRODUCTION**

## INTRODUCTION

Since the beginning of twentieth century, economic and social life of people and the functional system of industry and business, transportation, communications, educational and medical facilities and other activities of the community have undergone substantial changes due to spectacular developments in the fields of science and technology.

When the resources of a country fall short of its needs, the problem of efficient planning is not simple and it necessitates optimum utilization of the resources with a view to satisfying as many of the needs as possible in a balance manner. The knowledge of ratio of population totals of two characteristics is as important as, and some times more important than that of population totals and means. For instance, in socio economic survey, one may be interested in such ratio as per household and per capita income or expenditure, proportion of expenditure on different items, proportion of unemployed persons, sex ratio, birth rate, death-rate etc.

Estimation of yield rates in a crop survey and input output ratios in an industrial survey are of considerable importance. In estimating such ratios, commonly used procedure is to take the ratio of unbiased estimators of the numerator and the denominator of the population parameter as an estimator and such an estimator is termed as ratio estimator. It may be necessary to use a ratio estimator even for estimating the population or sub population mean and proportion.

In situation where the actual value of the denominator of the ratio is known, one may feel that it is sufficient to estimate only the numerator and that the population ratio could be estimated by dividing this estimator by the known value of the denominator. Such an estimator may not necessarily be very

efficient as compared to the ratio of the estimators of the numerator and denominator. In fact if the estimators of the numerator and the denominator are approximately proportional, i.e. if there is a linear regression between them and the regression line passes through origin, the latter procedure of estimation becomes more efficient than former. In this case the ratio of the estimators would be more stable than the ratio of the estimators of the numerator to denominator, in such a case it would be more suitable to use the product of the ratio of the estimators and the actual value of the parameter appearing in the denominator and this procedure of estimation is known as ratio method of estimation .Cochran (1940) has considered the problem of ratio method of estimation based on some suitable auxiliary variables (Murthy, M.N.(1967), Sampling theory and Methods, Calcutta: Statistical Publishing Society).

In survey sampling we are concerned with the estimation of population mean  $\bar{Y}_N$  under consideration of a certain characteristic Y. The precision of estimator of  $\bar{Y}_N$  can be increased by utilizing advance information available about suitable auxiliary characteristics X, which is highly correlated with Y. Ratio, product and regression methods of estimation are good example in this context. When there is a positive correlation between the characteristics Y and X, the ratio method of estimation is used and if there is negative and high correlation between the characteristics Y and X, the product method of estimation can be employed.

Apart from ratio and product estimators, for estimating population mean or population total, a number of estimators have been proposed which make use of auxiliary information. These estimators, however, need prior knowledge of one or more parameters of the population. Some of these estimators are due to Srivastava (1967), Walsh (1970), Gupta (1978), Vos (1980), Advaryu and Gupta (1983) and others etc. With proper choice of

value of constant appearing in their functional form, they are known to be more useful than mean per unit estimator, ratio estimator and product estimator.

In the present study an attempt has been made to compare some of estimators, considered by Naik, V. D. and Gupta, P. C. (1991) on weighted means (arithmetic, geometric and harmonic) of

1. Mean per unit and ratio estimators.
2. Mean per unit and product estimators.

It has been observed that all these estimators except the weighted harmonic mean of mean per unit and product estimators, have been studied by different researchers. All these estimators have a common constant that determines weight. The weights have been assigned conveniently so as to facilitate some direct theoretical comparisons among them. It has been observed that when the value of weight determining constant is chosen around the value of  $\rho C_Y/C_X$  these estimators perform quite efficiently.

Keeping in view, the importance of above points under references, the present study entitled "A comparative study of the estimators obtained from weighted means of mean per unit estimator and ratio / product estimators" has been undertaken with the following objectives.

1. To estimate the weighted arithmetic mean, weighted harmonic mean and weighted geometric mean of mean per unit estimator and ratio, product estimators.
2. To estimate the first order bias and common mean square error in optimum case of weighted arithmetic mean, weighted harmonic mean and weighted geometric mean of mean per unit estimator and ratio, product estimators.
3. To estimate the non-optimum MSE and their comparison with different values of weight and study the % increase in MSE of estimator as compared of MSE of linear regression estimator.
4. Comparison of the behavior of the relative biases  $\{n$  (absolute biases of the estimators)  $/ \bar{Y}\}$  for different weights  $(k-0.5, k+0.5)$ .

The bias will be estimated for all 4 objectives and least bias estimator will be searched out.

CHAPTER – II

**REVIEW OF LITERATURE**

## REVIEW OF LITERATURE

Cochran, W.G. (1940) has considered the problem of ratio method of estimation based on some suitable auxiliary variables and estimated the yields of cereal experiments by sampling for the ratio of grain to total produce.

Hajek, J. (1949) provided an almost unbiased estimator of the variance of the estimator. Another unbiased product estimator based on independent sub samples of equal size was given by Murthy, M.N. (1964).

Koop (1951) gave an expression for the bias and explored the possibilities of reducing it. Some authors, including Hartley and Ross (1954), Murthy and Nanjamma (1959), Williams (1961, 1963), Sukhatme (1962), Koop (1967), Singh, H.P., Upadhyaya, L.N and Iachan (1985), Singh H.P. and Kushwaha, K.S. (1987) etc. have suggested a number of methods for the construction of unbiased or almost unbiased ratio type estimators and studied their properties in detail both theoretically and empirically. Comparison of these and other estimators have also been made by Rao, J.N.K. (1965, 1967), Rao and Rao (1971), Sharot (1976) and Hutchison (1971) under certain models.

Hanson, Horvitz and Madow (1953) suggested the difference estimator, which was subsequently modified to give the linear regression estimator for the populations mean or its total.

Des Raj (1954) gave unbiased estimate of the variance of the estimator which was generally non-negative for samples with smaller probabilities. Rao and Vijayan (1977) gave an unbiased estimator which is non-negative for samples with larger probabilities.

The unbiased ratio type estimator was proposed by Hartley and Ross (1954) in the case of simple random sampling.

Robson (1957) and Murthy (1964) have studied the product estimator when the character  $y$  under study and the auxiliary character  $x$  are negatively correlated and this estimator can be used more efficiently than the mean per unit estimator.

Robson (1957), Goodman and Hartley (1958) have considered the variance of the ratio type estimator given as,

$$\hat{Y}_{UR} = \bar{r} \bar{X} + \{n(N-1)/(n-1)\}(\bar{y} - \bar{r} \bar{x}) \quad \bar{r} = (1/n) \sum r_i, (i=1,2,\dots,n)$$

Williams (1961) have given generalized ratio type estimators, of which the estimator

$\bar{r} \bar{X} + \{n(N-1)/(n-1)\}(\bar{y} - \bar{r} \bar{x})$ ,  $\bar{r} = (1/n) \sum r_i$ ,  $r_i = y_i/x_i$ , ( $i=1,2,\dots,n$ ) is a particular case.

Goodman and Hartley (1958) have shown that this estimator is more efficient than the usual biased ratio estimator, namely  $(\hat{Y}/\hat{X})X$ , if and only if the slope of the regression line of  $y$  on  $x$  is closer to  $(1/N) \sum_{i=1}^N (Y_i/X_i)$  than to  $(Y/X)$ .

When the auxiliary characteristics  $X$  is negatively correlated with the characteristics  $y$  under study Robson (1957) proposed the product method of estimation. Rediscovered by Murthy (1964) tarnishing a biased estimator of the population mean  $\bar{Y}_N$ . Robson (1957) also presented an unbiased product estimator by subtracting an unbiased estimate of the bias.

A general technique of obtaining almost unbiased ratio estimators for any order of approximation has been considered by Murthy and Nanjamma (1959). This problem has been examined on similar lines for simple random sampling by Quenouille (1956) and Durbin (1959) has shown that for certain populations the corrected

ratio estimator is more efficient than the biased ratio estimator. (Murthy, M.N. 1967)

The technique of changing the selection procedure for obtaining unbiased ratio estimators has been considered in a generalized form by Nanjamma, Murthy and Sethi (1959), who have also given the actual modification needed in commonly used sampling schemes.

Ratio type estimators based on  $k$  groups obtained by dividing the sample at random into  $k$  groups have also been proposed by Murthy and Nanjamma (1959) and Pascual (1961). A question arises about the optimal value of  $k$ . Rao, Poduri, S.R.S. and Rao J.N.K. (1971) have also investigated this problem using a linear regression model and found that  $n$  is the optimal value for  $k$ .

L.A Goodman (1960) has considered the question of obtaining the variance and variance estimators of the product estimators.

Murthy (1964) has discussed the uses of the product method of estimation and has given a technique of obtaining unbiased product estimators based on interpenetrating sub-samplings.

Walsh (1970), Reddy (1973, 1974), Gupta (1978), Sahai (1979), Vos (1980), Adhvaryu and Gupta (1983) etc. have proposed certain estimators which under some realistic conditions are as much efficient as the linear regression estimator in the optimum case.

Searl (1964) used Coefficient of Variation (C.V.) of study character at estimation stage. In practice this C.V. is seldom known. Motivated by Searl's work, Sisodiya and Dwivedi (1981) used the known C.V. of the auxiliary character for estimating population mean of a study character in ratio method of estimation.

Mohanty and Das (1971) have proposed the technique of transformation of auxiliary variate in sample surveys to reduce the bias and mean square error.

Many biased ratio type, product type transformed estimators obtained through linear combination of ratio or product and usual unbiased estimators are available for estimating the population mean, when auxiliary information is available on auxiliary variable using simple random sampling. The classical ratio and product estimators under Systematic sampling scheme was proposed by Swain (1964), and Shukla (1971) respectively and their properties were studied which was later generalized to a class of estimators by Kushwaha, K.S. and Singh, H.P. (1989).

Kushwaha, K.S. (1991) has proposed a "Class of almost unbiased dual to product estimators in sample survey, which has also been referred in a text book "The theory and methods of survey sampling written by Primal mukhopadhyay, I.S.I. Cal. (1998) and entire matter has been republished in special issue of "Dr. Radhakrishanan samman (1992-93), U.G.C. Bhopal.

Singh, M.P. (1965, 1967) has suggested the ratio cum product estimator for estimating the population total of the study variable when supplementary information is available on two auxiliary variables.

The problem of ratio and product of two population means has been discussed by various authors including Singh, M.P. (1965, 67, 69), Rao and Pereira (1968), Shah and Shah (1978), Tripathi (1980), Singh R.K. (1982 a, b) Singh and Singh (1984a, b), Singh H P. (1986a, b)

Upadhyaya, L.N., Kushwaha, K.S. and Singh, H.P. (1991) have proposed a modified chain ratio type estimator in two phase

sampling using multiauxiliary information and studied in details and it has also been referred in a book " Advance sampling theory with application" written by Surjinder Singh. St. Cloude State University, Department of statistics, St. cloud, M.N. U.S.A. and published by "Kluwer Academic Publishers, Dordrecht / Boston/ London (2003)

Rao, J.N.K., Ramachandran, V. (1974) studied the comparison of the separate and combined ratio estimators.

A general class of estimators of the variance of the ratio estimator is considered which includes two standard estimators'  $v_0$  and  $v_2$  and approximates another estimator  $v_H$  suggested by Royall and Eberhardt (1975)

The classical ratio and product estimators are consistent but biased. For their properties, one can refer to Cochran (1977), Murthy (1967), Koop (1972), Sukhatme (1954) and Des Raj (1968) In a situation where the correlation between  $y$  and  $x$  is positive Hansen and Hurwitz (1943) claimed that the bias of ratio estimator is usually negligible "Later on, it was found that the bias was important disadvantage, which led Lahiri (1951) to devise a method of sampling to eliminate it.

Yates (1981) and others have given their discussions however, these have been confined to combining ratio or regression estimates from the matched portion of the sample with a mean per unit estimate based on the current occasion.

Upadhyaya, Singh and Vos (1985) and Upadhyaya and Singh (1985) among others have made some studies using supplementary information on single or more auxiliary Variables.

Iachan, Singh and Upadhyaya (1983) and Iachan, R., Singh, H.P. and Upadhyaya, L.N. (1987) have also suggested a number of unbiased product estimators and studied their properties , Such

estimators are only applicable when the population mean  $\bar{X}_N$  of auxiliary character  $X$  is known in advance . In many practical situations the information about  $\bar{X}_N$  is not known, thus the estimators discussed by the authors named above have no utility. In such cases the usual thing to do is to make recourse to the technique of double sampling to get unbiased estimate of  $\bar{X}_N$ .

Several methods have been proposed to estimate the sampling variance of ratio estimates in complex samples Wolter (1985), Hansen and Tepping (1985) studied some of those variance estimators and found that a high coefficient of variation (CV) of the denominator of a ratio estimate is indicative of a biased estimate of the standard error of a ratio estimate. Using the same populations, Kovar (1985) and Kovar, Rao, and Wu (1988) repeated the research and showed that the relation between a high CV and bias in standard errors is weak. In light of these conflicting findings, this study uses substantially different populations and design choices taken from the National Assessment of Educational Progress (NAEP) to further investigate the relationship between bias, the CV, and the number of strata, which have also been found to be an indicator of bias.

A general class of almost unbiased estimators has been proposed and studied by Kushwaha, K.S and Singh, H.P. (1989) for estimating population mean  $\bar{Y}$  of the characteristic under study  $Y$  when auxiliary information is available using systematic sampling plan. Explicit expressions for the variance of class of estimators are obtained to the first order of approximation. Minimum variance unbiased estimators (optimum estimators) in the class have also been investigated. The class of estimators proposed by Singh, H.P. and Kushwaha, K.S. (1989) comes out to be a particular case of this class of estimators.

Naik, V.D. and Gupta, P.C. (1991, a, b) worked on a comparative study with the Mean per unit Estimator, the ratio estimator and the product estimators.

The use of ratio method of estimation in successive sampling was first introduced by Sen, Sellers and Smith (1975). Later Art'es, Rueda and Arcos (1998), Art'es and Garc'ia (2000), Art'es and Garc'ia (2001) have shown, in this context, that the combined estimator that uses a double sampling ratio estimator for the matched part of the sample is more accurate than the simple estimator  $y$  when the auxiliary variable is positively related to the regressed variable  $y_i$  and it is verified that  $\rho > (1/2) C_x/C_y$ , see Sen, Sellers and Smith, (1975).

Recently Singh and Tailor (2003) proposed a modified ratio estimator by using the known value of correlation coefficient.

CHAPTER – III  
**METHODOLOGY**

## METHODOLOGY

This chapter deals with the method and procedure used for the study. The different steps under taken are listed below and details under each step are explained in the succeeding parts of chapter.

### 3.1 Estimators

Let  $(u_1, u_2, \dots, u_n)$  be a random sample of size  $n$  drawn using SRSWR (simple random sampling with replacement) technique from a population  $(U_1, U_2, \dots, U_N)$  of size  $N$ . Further, let  $y_i$  and  $x_i$  be the values of character under study  $Y$  and the auxiliary variable  $X$  respectively. We consider the following estimators for the population parameter (population mean)  $\bar{Y}$ .

$$\begin{aligned}
 \bar{y}_{AR} &= (1-w)\bar{y} + w\bar{y}_R \\
 \bar{y}_{HR} &= ((1-w)\bar{y} + w/\bar{y}_R)^{-1} \\
 &= \bar{y}\bar{x} / \{\bar{X} + w(\bar{x} - \bar{X})\} \\
 \bar{y}_{GR} &= \bar{y}^{(1-w)} \bar{y}_R^w \\
 &= \bar{y} (\bar{x} / \bar{X})^w
 \end{aligned}
 \tag{3.1.1}$$

Where  $\bar{y}$  and  $\bar{y}_R$  are mean per unit estimator and ratio estimator respectively, for estimating population mean  $\bar{Y}$ ,  $\bar{x}$  and  $\bar{X}$  are sample mean and population mean respectively, of the auxiliary character  $X$ .

Also  $\bar{y}_{AR}$ ,  $\bar{y}_{HR}$  and  $\bar{y}_{GR}$  are the weighted arithmetic mean weighted harmonic mean and weighted geometric mean respectively, of  $\bar{y}$  and  $\bar{y}_R$  and have been studied by Vos (1980), Walsh (1970) and Srivastava (1967) respectively.

Also consider the weighted arithmetic mean, weighted harmonic mean and weighted geometric mean of  $\bar{y}$  and  $\bar{Y}_P$  written as follows.

$$\begin{aligned}
 \bar{y}_{AP} &= (1+w)\bar{y} + w\bar{y}_P \\
 \bar{y}_{HP} &= \left( \frac{1+w}{\bar{y}} - \frac{w}{\bar{y}_P} \right)^{-1} \\
 &= \bar{y}\bar{x} / \{ \bar{X} + (1+w)(\bar{x}-\bar{X}) \} \\
 \bar{y}_{GP} &= \bar{y}^{(1+w)} \bar{y}_P^w \\
 \bar{y}_{GP} &= \bar{y} (\bar{X} / \bar{x})^w
 \end{aligned}
 \tag{3.1.2}$$

Where  $\bar{y}_P$  is product estimator.

Among these estimator  $\bar{y}_{AP}$  has been studied by Vos (1980) and  $\bar{y}_{GP}$  has been studied by Srivastava (1967), which is identical to  $\bar{y}_{GR}$ .

In all three estimators cited above,  $w$  is an unknown constant. It has been observed, as will be observed in subsequent sections, that the optimum value of this unknown constant  $w$  remains the same for all the estimators considered have in.

### 3.2 First order bias and MSE

Following Sukhatme et al.(1983) the, first order bias of these estimators have been obtained by Naik, V.D. and Gupta, P.C. (1991) ignoring finite population correction and are given in table 3.1.

**Table 3.1 First order bias of weighted (arithmetic, geometric and harmonic) means of mean per unit estimator and ratio/ product estimator**

| Estimator      | First order bias                              |
|----------------|---|
| $\bar{y}_{AR}$ | $w\bar{Y}C_x^2\{(w-\rho C_y/C_x)+(1-w)\}/n$   |
| $\bar{y}_{HR}$ | $w\bar{Y}C_x^2\{(w-\rho C_y/C_x)\}/n$         |
| $\bar{y}_{GR}$ | $w\bar{Y}C_x^2\{(w-\rho C_y/C_x)+(1-w/2)\}/n$ |
| $\bar{y}_{AP}$ | $w\bar{Y}C_x^2\{(w-\rho C_y/C_x)-w\}/n$       |
| $\bar{y}_{HP}$ | $w\bar{Y}C_x^2\{(w-\rho C_y/C_x)+1\}/n$       |

Where  $C_y$  and  $C_x$  are the coefficient of variation of  $y$  and  $x$  respectively, and  $\rho$  is correlation coefficient between  $(Y, X)$ .

Also, up to first order approximation they (3.1.1, 3.1.2) have common MSE and are given as follows.

$$\text{MSE (3.1.1, 3.1.2)} = \bar{Y}^2 (C_y^2 + w^2 C_x^2 - 2\rho C_y C_x) / n \quad \dots\dots\dots (3.2.1)$$

### 3.3 Optimum case

Optimum weight ( $w$ ) for (3.1.1 and 3.1.2) and optimum MSE's are given respectively as.

$$\text{Opt (w)} = \rho C_y / C_x \quad \dots\dots\dots (3.2.2)$$

And

$$\text{MSE (3.1.1, 3.1.2)} = \bar{Y}^2 (1 - \rho^2) C_y^2 / n \quad \dots\dots\dots (3.2.3)$$

Here the optimum MSE (3.1.1, 3.1.2) is same as that of linear regression estimator  $(\bar{y}_{lr} = \bar{y}_n + (\bar{X} - \bar{x}_n))$ . So, in the optimum case, all these estimators are equally efficiently as far as first order MSE's are concerned.

Further the expression of optimum first order bias of these estimators can be obtained by substituting the value of  $w$  from (3.2.2) in the expression given in table (3.1.)

It can be easily seen that in optimum case, the estimator  $\bar{y}_{HR}$ , which is weighted harmonic mean of  $\bar{y}$  and  $\bar{y}_R$  becomes unbiased and hence should be preferred to over all other estimators under consideration.

### 3.4 Non optimum case

If the value of  $\rho C_y / C_x$  is known then all these estimators are equally efficient and their efficiency is same as that of linear regression estimator as far as the first order mean square error is concerned. However, if the first order bias is considered then the estimator  $\bar{y}_{HR}$  may be preferred. In general, the true value of  $\rho C_y / C_x$  is hardly known.

suppose that true value of  $\rho C_y / C_x$  is not known but if it is known that it belongs to neighborhood of a constant  $m$ , say in the interval  $(m-b, m+b)$  where  $b$  is a small positive constant with  $w \neq m$  ( $\neq \rho C_y / C_x$ ), the difference between first order mean square error of any of these estimators and that of linear regression estimator will be less than the quantity  $\bar{Y}^2 b^2 (C_x)^2 / n$ . Thus when the sample size is reasonably large, the variation in auxiliary character is small and the deviation of weight from its optimum value is not large then the efficiency of these estimators will be quite close to that of linear regression estimator as far as first order MSE is concerned, If  $\rho C_y / C_x$  belongs to the interval  $(0.25, 0.75)$  and if any of these estimators is used with  $w = 0.5$  then its first order MSE will be greater than that of linear regression estimator by quantity less than  $\bar{Y}^2 (C_x)^2 / (16n)$ .

For any given value of  $w$ , when first order MSE is concerned then all of them are equally efficient. Hence if a choice is to be made from these estimators then the sensitivity of the first order bias of the given estimator with respect to the deviation of value of  $w$  from  $\rho C_Y / C_X$  may be investigated empirically.

### 3.5 Correlation coefficient ( $\rho$ )

Coefficient of correlation was used to find out the closeness of relationship between two variables. For this purpose the following expression to compute the value of  $\rho$  has been applied formulas was used:

$$\rho = \frac{\Sigma XY - (\Sigma X)(\Sigma Y) / N}{\sqrt{[(\Sigma X^2) - (\Sigma X)^2 / N][(\Sigma Y^2) - (\Sigma Y)^2 / N]}} \quad \dots (3.4.1)$$

Where,

$N$  = number of observations

$\Sigma X$  = sum of scores of  $X$  variable

$\Sigma Y$  = sum of scores of  $Y$  variable

$\Sigma XY$  = sum of product of scores of  $X$  and  $Y$  variable

$\Sigma Y^2$  = sum of the squares of the values of dependent variables

$\Sigma X^2$  = sum of the squares of the values of independent variables

### 3.6 Relative change in MSE

$$= \{(\text{Succeeding MSE} - \text{Preceding MS.E}) / \text{Preceding MSE}\} \times 100$$

### 3.7 Population Standard deviation

Standard deviation usually denoted by the Greek letter small sigma ( $\sigma$ ) is the positive square root of the arithmetic mean of the squares of the deviations of the given values from their arithmetic mean. For the frequency distribution of the random variable say  $X$  (Area)

$$\sigma = \sqrt{\left\{ \frac{1}{N} \sum_{i=1}^k f_i (X_i - \bar{X})^2 \right\}}, \quad i = 1, 2, \dots, k \quad \dots\dots\dots (3.6.1)$$

Where  $\bar{X}$  is the arithmetic mean of the random variable  $X$  and  $\sum_{i=1}^k f_i = N$ , is the number of units in the population and  $k$  is number of distinct values.

### 3.8 Estimator

An estimator is a rule or method for estimating a population parameter. It is generally expressed as a function of sample variates. An estimator is itself a random variable.

### 3.9 Estimate

A particular value for an estimator obtained from a set of sample values of a random sample is known as estimate. Few units are randomly selected from a population and then observations are taken on these selected units. A constant value for a characteristic under study is worked out from these sample observations. The constant, so obtained, is known as an estimate and stands as an estimate of population parameter. For example sample mean  $\bar{x}$  is an estimate of population mean  $\bar{X}$  and sample variance  $s^2$  is an estimate of population mean square  $S^2$ . Here  $s^2$  is also known as constant estimate of population variance.

### 3.10 Selection with replacement

A unit is selected from a population with a known probability and the unit is returned to the population before the selection of next draw is made. Thus in this method at each selection, the population size remains constant and the probability at each selection or draw remains the same. Under this sampling plan, a unit has chance of being selected more than once.

### 3.11 Coefficient of variation:

The coefficient of dispersion based upon standard deviation expressed in percentage (%), known as coefficient of variation (CV) i.e.

$$CV(X) = 100 \times \sigma / \bar{X} \quad \dots\dots\dots (3.10.1)$$

According to professor Carl Pearson who suggested this measure CV (X) is the percentage variation in the mean, where the standard deviation is considered as the total variation in the mean ( $\bar{X}$ ).

### 3.12 Test of significance of correlation coefficient

Test of significance of correlation coefficient means to test the hypothesis, whether the two characteristics x and y are linearly related or not in the population i.e. we test, the hypothesis

$$H_0: \rho = 0 \text{ vs. } H_1: \rho \neq 0 \quad \dots\dots\dots(3.11.1)$$

Where  $H_0$  = Null hypothesis and  $H_1$  is alternative hypothesis.

The test statistic for testing  $H_0$  is the student's t statistic which is defines as follows.

$$t = (|r| \sqrt{n-2}) / \sqrt{(1-r^2)} \quad \dots\dots\dots(3.11.2)$$

This t statistic follows student's t distribution with (n-2) degree of freedom. If the calculated value of t statistic is greater than the corresponding table value at  $\alpha\%$ , (0.05) level of

significance and  $(n-2)$  degree freedom, we reject  $H_0$ , and otherwise we accept  $H_0$ . Rejection of  $H_0$  leads to the conclusion that the two characteristics  $(X, Y)$  are linearly correlated. This means that the correlation between two characteristics is worth considering.

If  $H_0$  is accepted, it means that the two characteristics  $(X, Y)$  are not linearly correlated and in such situation it is useless to apply the regression analysis to the data because in such situation we can not get an increased precision of the estimate at all.

### **3.12 Selection of area and crops for empirical study –**

An attempt has been made to compare some of estimators, considered by Naik, V.D. and Gupta, P.C. (1991) on weighted means (arithmetic, geometric and harmonic) of

Mean per unit and ratio estimators.

Mean per unit and product estimators.

It has been observed that when the value of weight (constant) is chosen around the value of  $\rho C_y/C_x$  these estimators perform quite efficiently. The first order approximation of bias and mean square error of these estimators as well as their optimum mean square error have been compared with help of the empirical study made by taking different live data (like area, and yield) For this empirical study, the 15 years (1990-2005) secondary data have been taken from Agricultural statistics published by Directorate of Agriculture, M.P. State of India (See appendix 1).

CHAPTER – IV

**APRIOR ANALYSIS AND STATISTICAL  
DECISION**

## A PRIOR ANALYSIS AND STATISTICAL DECISION

**Table 4: Study for significance of correlation coefficient for 15 years**

|                           | <b>Paddy</b>  | <b>Jowar</b>  | <b>Maize</b>  | <b>Bajra</b>  | <b>Kodo kutki</b> |
|---------------------------|---------------|---------------|---------------|---------------|-------------------|
| $\Sigma X$                | 2758          | 14153         | 11478         | 3019          | 7198              |
| $\Sigma Y$                | 12092         | 13410         | 21695         | 15398         | 3656              |
| $\Sigma X/N$              | 1650.533      | 943.533       | 765.2         | 201.26        | 479.86            |
| $\Sigma Y/N$              | 806.133       | 894           | 1446.33       | 1026.53       | 243.733           |
| $\Sigma XY$               | 20003522      | 12686001      | 1668168       | 3112766       | 1758807           |
| $\sigma_x$                | 66.646        | 312.054       | 174.44        | 161.178       | 82.53             |
| $\sigma_y$                | 175.584       | 139.265       | 318.871       | 211.19        | 37.0971           |
| $S_x$                     | 68.985        | 323.00        | 180.566       | 166.83        | 85.435            |
| $S_y$                     | 181.7470      | 144.153       | 330.00        | 218.604       | 38.399            |
| $C_x$                     | 0.04179       | 0.3423        | 0.2359        | 0.828         | 0.1780            |
| $C_y$                     | 0.2254        | 0.16424       | 0.2282        | 0.212         | 0.157             |
| $\rho$                    | 0.2579        | 0.0509        | 0.096         | 0.0267        | 0.0961            |
| $K=\rho C_y/C_x$          | 1.39          | 0.0239        | 0.0935        | 0.00683       | 0.0847            |
| Calculate value of t<br>→ | 0.96247       | 0.183         | 0.3477        | 0.0963        | 0.348             |
| Decision                  | Insignificant | Insignificant | Insignificant | insignificant | Insignificant     |

|                           | Other Cereals | Kharif Cereals | Tur           | Urd           | Moong         |
|---------------------------|---------------|----------------|---------------|---------------|---------------|
| $\Sigma X$                | 1150          | 61756          | 5049          | 6778          | 1532          |
| $\Sigma Y$                | 5415          | 13423          | 1208          | 4837          | 4739          |
| $\Sigma X / N$            | 76.66         | 4117.00        | 336.6         | 451.86        | 102.133       |
| $\Sigma Y / N$            | 361           | 894.866        | 805.4         | 322.46        | 315.93        |
| $\Sigma XY$               | 392704        | 55129727       | 4087928       | 2910662       | 485440        |
| $\sigma_x$                | 30.760        | 338.627        | 31.36         | 66.18         | 16.86         |
| $\sigma_y$                | 117.43        | 137.09         | 95.270        | 39.368        | 35.015        |
| $S_x$                     | 31.840        | 35051          | 32.46         | 68.50         | 17.45         |
| $S_y$                     | 121.557       | 14190          | 98.614        | 40.7498       | 36.244        |
| $C_x$                     | 0.41530       | 0.085136       | 0.0964        | 0.151         | 0.170         |
| $C_y$                     | 0.336         | 0.1585         | 0.1224        | 0.1263        | 0.1147        |
| $\rho$                    | -0.414        | -0.1919        | 0.4788        | 0.1263        | 0.1614        |
| $K = \rho C_y / C_x$      | -0.334        | -0.3572        | 0.607936      | 0.1065        | 0.10889       |
| Calculate value of t<br>→ | 1.6398        | 0.705          | 1.9663        | 0.46312       | 0.5896        |
| Decision                  | Insignificant | Insignificant  | Insignificant | insignificant | Insignificant |

|                        | Kulthi        | Kharif Pulses | Kh. Food Grains | Ground nut    | Soybean       |
|------------------------|---------------|---------------|-----------------|---------------|---------------|
| $\Sigma X$             | 698           | 14178         | 75934           | 3396          | 57551         |
| $\Sigma Y$             | 3778          | 7380          | 122382          | 14616         | 13922         |
| $\Sigma X/N$           | 46.53         | 945.2         | 62113468        | 226.4         | 3836.7        |
| $\Sigma Y/N$           | 251.866       | 492           | 5062.26         | 974.4         | 928.133       |
| $\Sigma XY$            | 176230        | 6981838       | 818.8           | 3288945       | 53448153      |
| $\sigma_x$             | 11.09         | 81.05         | 396.9126        | 17.80         | 741.179       |
| $\sigma_y$             | 47.18         | 49.26         | 112.82          | 164.86        | 133.865       |
| $S_x$                  | 11.482        | 83.89         | 410.84          | 14.43         | 767.193       |
| $S_y$                  | 48.84         | 50.99         | 116.78          | 170.652       | 138.563       |
| $C_x$                  | 0.246         | 0.0887        | 0.08115         | 0.0814        | 0.1999        |
| $C_y$                  | 0.193         | 0.1036        | 0.1426          | 0.1751        | 0.1492        |
| $\rho$                 | 0.0543        | 0.1045        | -0.9124         | -0.4567       | 0.0222        |
| $K = \rho C_y / C_x$   | 0.04260       | 0.1220        | -0.1603         | -0.9824       | 0.01656       |
| Calculate value of t → | 0.1960        | 0.3788        | 0.3303          | 1.850         | 0.80060       |
| Decision               | insignificant | Insignificant | Insignificant   | insignificant | Insignificant |

|                              | Sesamum       | Niger         | Castor        | Kharif<br>Oil seeds | Sugar cane    |
|------------------------------|---------------|---------------|---------------|---------------------|---------------|
| $\Sigma X$                   | 2369          | 1844          | 43            | 65212               | 609           |
| $\Sigma Y$                   | 4008          | 3014          | 4777          | 13085               | 59137         |
| $\Sigma X/N$                 | 157.93        | 122.93        | 2.866         | 4347.46             | 40.6          |
| $\Sigma Y/N$                 | 267.2         | 200.933       | 318.466       | 872.33              | 3942.466      |
| $\Sigma XY$                  | 626243        | 371447        | 13869         | 57061227            | 2402619       |
| $\sigma_x$                   | 26.566        | 12.839        | 1.499         | 693.25              | 5.571         |
| $\sigma_y$                   | 54.1826       | 37.06         | 48.185        | 107.375             | 284.79        |
| $S_x$                        | 27.499        | 13.290        | 1.5522        | 717.58              | 5.766         |
| $S_y$                        | 56.08         | 38.365        | 49.876        | 111.144             | 294.789       |
| $C_x$                        | 0.1741        | 0.10811       | 0.54148       | 0.1650              | 0.1420        |
| $C_y$                        | 0.20989       | 0.1909        | 0.15661       | 0.1274              | 0.0747        |
| $\rho$                       | -0.3127       | 0.129708      | 0.16139       | 0.1563              | 0.06961       |
| $K=\rho C_y/C_x$             | -0.3769       | 0.227         | 0.04667       | 0.57056             | 0.03661       |
| Calculate<br>value of t<br>→ | 1.1869        | 0.47165       | 0.589629      | 0.57056             | 0.25159       |
| Decision                     | insignificant | Insignificant | Insignificant | insignificant       | Insignificant |

|                                    | Wheat       | Barley        | Other Cereals | Rabi Cereals | Gram          |
|------------------------------------|-------------|---------------|---------------|--------------|---------------|
| $\Sigma X$                         | 59463       | 1257          | 115           | 60835        | 35984         |
| $\Sigma Y$                         | 25309       | 18127         | 10588         | 24536        | 13103         |
| $\Sigma X/N$                       | 3964.2      | 83.8          | 7.666         | 4055.66      | 2398.933      |
| $\Sigma Y/N$                       | 1687.266    | 1208.46       | 705.86        | 1635.73      | 873.533       |
| $\Sigma XY$                        | 101142652   | 1518486       | 76330         | 100243897    | 31598292      |
| $\sigma_x$                         | 415.326     | 4.1182        | 3.57          | 416.859      | 245.66        |
| $\sigma_y$                         | 160.12764   | 122.32        | 201.332       | 142.270      | 89.775        |
| $S_x$                              | 429.9040    | 4.262         | 3.696         | 431.49       | 254.291       |
| $S_y$                              | 165.747     | 126.61        | 208.39        | 147.26       | 92.9261       |
| $C_x$                              | 0.10844     | 0.05086       | 0.4821        | 0.106        | 0.1060        |
| $C_y$                              | 0.098234    | 0.1047        | 0.2952        | 0.0900       | 0.1063        |
| $P$                                | 0.814686    | -0.07366      | -0.4491       | 0.82515      | 0.4989        |
| $K = \rho C_y / C_x$               | 0.7379      | -0.15163      | -0.2749       | 0.70059      | 0.50031       |
| Calculate value of $t \rightarrow$ | 5.0653221   | -0.2663       | -1.8122       | 5.2665       | 2.075         |
| Decision                           | significant | Insignificant | Insignificant | significant  | Insignificant |

|                        | Peas        | Lentil        | Teora         | Other Pulses  | Rabi Pulses |
|------------------------|-------------|---------------|---------------|---------------|-------------|
| $\Sigma X$             | 2490        | 6693          | 944           | 220           | 46331       |
| $\Sigma Y$             | 6206        | 7118          | 10540         | 7041          | 11771       |
| $\Sigma X/N$           | 1050249     | 446.2         | 62.933        | 14.666        | 3088.733    |
| $\Sigma Y/N$           | 166         | 474.533       | 702.666       | 469.4         | 784.73      |
| $\Sigma XY$            | 413.733     | 3174754       | 660955        | 90159         | 36544476    |
| $\sigma_x$             | 32.59       | 62.677        | 12.20         | 6.609         | 309.134     |
| $\sigma_y$             | 51.92       | 35.00         | 189.958       | 309.47        | 74.60       |
| $S_x$                  | 33.73       | 64.877        | 12.63         | 6.841         | 319.98      |
| $S_y$                  | 53.744      | 36.237        | 196.626       | 320.33        | 77.226      |
| $C_x$                  | 0.2032      | 0.1453        | 0.2007        | 0.466         | 0.1035      |
| $C_y$                  | 0.1299      | 0.07636       | 0.2798        | 0.6824        | 0.098       |
| $\rho$                 | 0.7899      | -0.0394       | -0.0679       | -0.4272       | 0.5405      |
| $K=\rho C_y/C_x$       | 0.5049      | -0.02070      | -0.09466      | -0.6255       | 0.51178     |
| Calculate value of t → | 4.644       | 0.1421        | 0.2453        | 1.703         | 2.3163      |
| Decision               | significant | Insignificant | insignificant | insignificant | Significant |

|                           | Rabi Food Grains | Rape / Mustard | Linseed     | Sunflower and Others | Rabi Oilseeds |
|---------------------------|------------------|----------------|-------------|----------------------|---------------|
| $\Sigma X$                | 107166           | 8613           | 3492        | 419                  | 12524         |
| $\Sigma Y$                | 19014            | 12955          | 5334        | 3675                 | 10544         |
| $\Sigma X / N$            | 7144.4           | 574.2          | 232.8       | 27.93                | 834.93        |
| $\Sigma Y / N$            | 1267.6           | 863.66         | 355.6       | 263.56               | 702.93        |
| $\Sigma XY$               | 136794465        | 7490689        | 1222431     | 53921.8667           | 8771810       |
| $\sigma_x$                | 646.08           | 89.335         | 63.8740     | 25.60                | 147.90        |
| $\sigma_y$                | 113.589          | 123.20         | 35.7916     | 189.58               | 116.135       |
| $S_x$                     | 668.76           | 92.47          | 66.115      | 26.448               | 153.100       |
| $S_y$                     | 117.57           | 127.527        | 37.047      | 195.801              | 120.211       |
| $C_x$                     | 0.0936           | 0.1610         | 0.28400     | 0.9468               | 0.183         |
| $C_y$                     | 0.09275          | 0.147          | 0.1041      | 0.7429               | 0.1710        |
| $\rho$                    | 0.8637           | 0.3145         | -0.5635     | -0.822               | -0.123        |
| $K = \rho C_y / C_x$      | 0.9160           | 0.51178        | -0.20655    | -0.6449              | -1.1149       |
| Calculate value of t<br>→ | 6.1787           | 1.1945         | 2.4593      | 5.20426              | 0.4468        |
| Decision                  | Significant      | Insignificant  | Significant | Significant          | insignificant |

## **Conclusion:-**

The values of correlation coefficient between two characteristics y (yield) and X (area) for 36 crops have been worked out by taking the secondary data for 15 years from the reports of agricultural statistics published by directorate of agriculture, Madhya Pradesh. The significance test for these correlation coefficient has also been applied by using student t statistic. The calculated values of correlation coefficient along with the value of test statistic t have been put in the table 4. The conclusion of the test has been drawn at 5% level of significance and is also put in the table 4.1 where the tabulated value of t statistic at 5 % level of significance and 13 degree of freedom is 2.16.

Thus from the above tables we say that Linseed, Rabi Food Grain, Wheat, Pea, Sunflower, Rabi Pulse, Rabi Cereals have significant correlation coefficient between two characteristics yield and area. So we take the sample of only those seven crops for further study. By using simple random sampling with replacement for 7 years from a list of 15 years. For this purpose we have used here Tippet (1927) random number table (appendix 3 and 4)

CHAPTER – V

**RESULTS AND DISCUSSION**

## RESULT AND DISCUSSION

### Sample Selection procedure

Using two figure numbers given in column 1, 2, for Wheat, 3,4 for Sunflower 5, 6 for Rabi Cereal, 10,11 for Pea of the table given in appendix 3 and 1,2 for Rabi Food Grain, 3,4 for Linseed, 22,23 in appendix 3 for Rabi pulses. Rejecting numbers greater than 15 and accepting repetition. The procedure rejects a large numbers of random numbers a device commonly employed to avoid the rejection of such large numbers is to divide a random number by 15, and to choose the serial number 1 through 15 corresponding to the remainder. However it is necessary to reject random no 31 to 99 (besides, 00) in adopting this procedure as otherwise years with serial no. 1 to 15 will get a large change of rejection.

If we use this procedures and also the figure of random numbers as given in column (1, 2), (5, 6), (3, 4), (10, 11), etc. we obtain the sample of years with serial number given below –

Wheat-12, 01, 08, 03,10,01,13

Rabi Cereals- 13,08,02,09,04,14,14

Sunflower – 09, 2, 11, 10,12,06,03

Pea- 11,15,03,10,12,10,07

Rabi Food Grain- 04,03,01,05,05,05,06

Linseed-15, 03, 14, 11,09,11,05

Rabi Pulses-11, 15, 12, 10,01,04,11

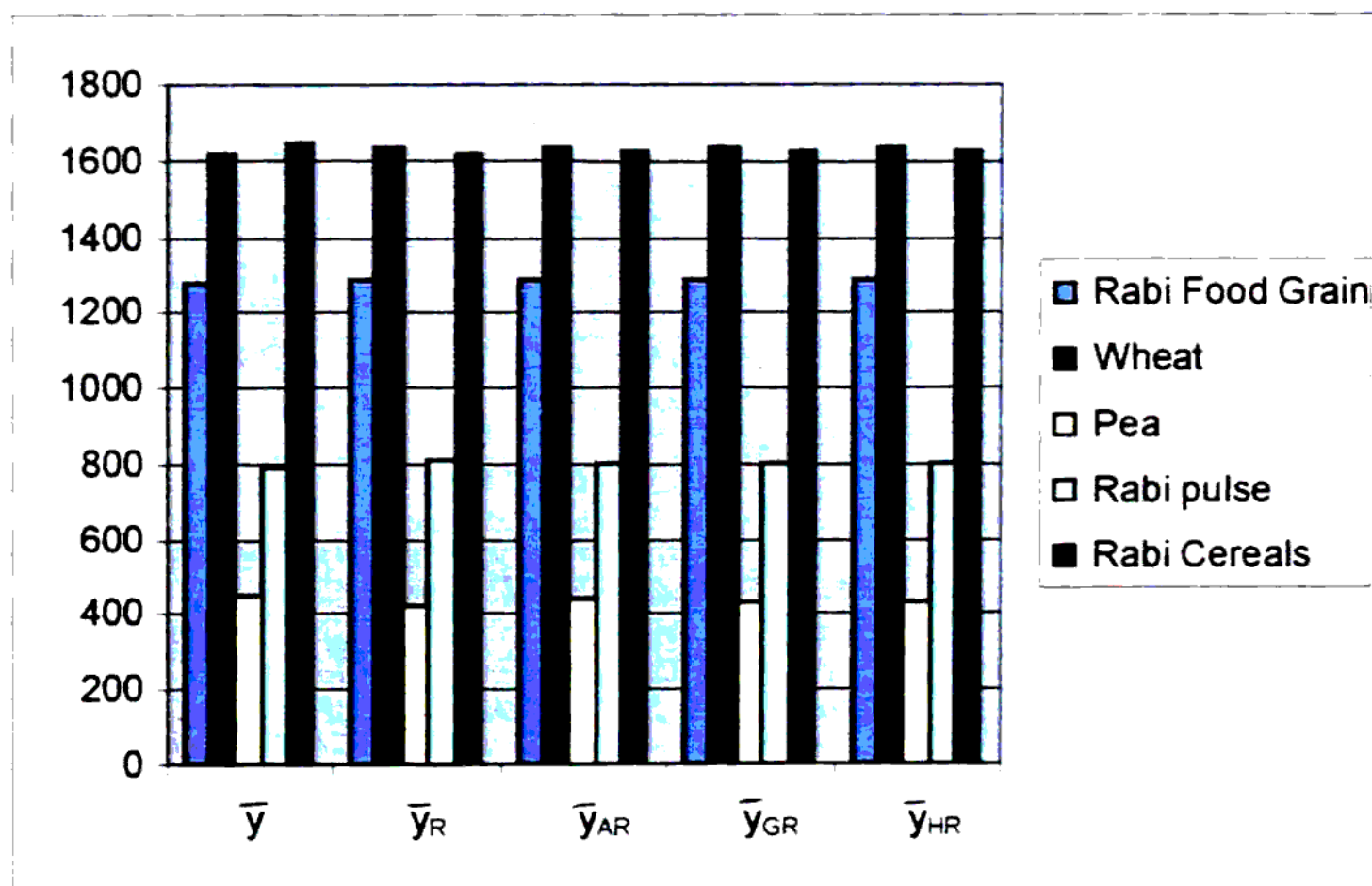
Our samples corresponding to these random numbers are in table 5.1

**Table 5.1 Selected samples from population of 35 crops of 7 years with the help of Tippert (1927) random number table**

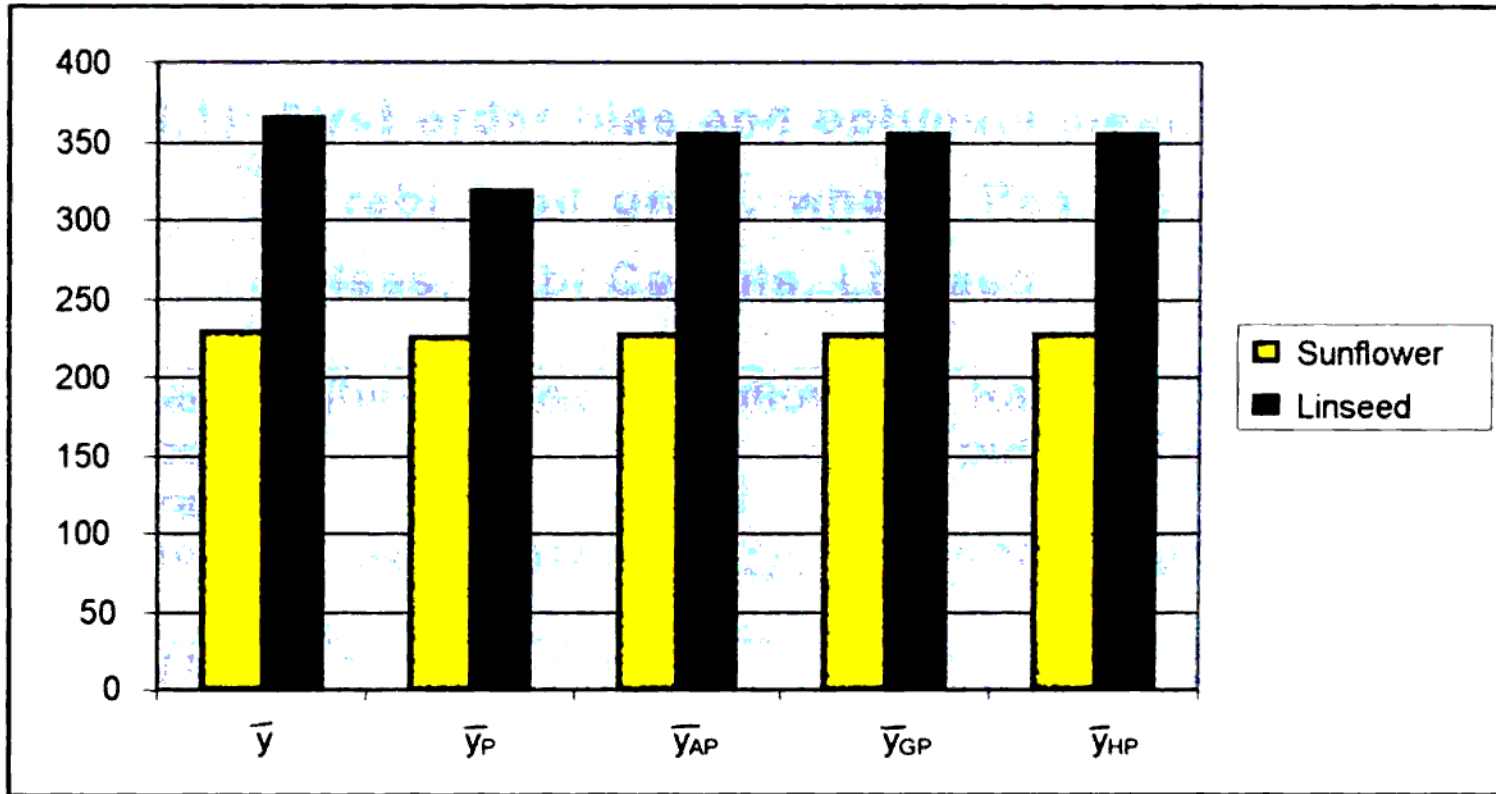
| Wheat |       | Rabi Cereals |       | Sunflower |       | Pea  |       | Rabi Food Grain |       | Linseed |       | Rabi Pulses |       |
|-------|-------|--------------|-------|-----------|-------|------|-------|-----------------|-------|---------|-------|-------------|-------|
| Area  | Yield | Area         | Yield | Area      | Yield | Area | Yield | Area            | Yield | Area    | Yield | Area        | Yield |
| 169   | 421   | 3467         | 1451  | 6         | 306   | 169  | 421   | 6914            | 1293  | 133     | 394   | 3514        | 835   |
| 219   | 483   | 4595         | 1581  | 64        | 109   | 219  | 483   | 6410            | 1120  | 276     | 326   | 2697        | 716   |
| 113   | 354   | 3544         | 1457  | 3         | 333   | 113  | 354   | 6653            | 1188  | 143     | 434   | 3298        | 841   |
| 196   | 513   | 4670         | 1791  | 7         | 286   | 196  | 513   | 7401            | 1362  | 162     | 333   | 3354        | 890   |
| 179   | 472   | 4147         | 1637  | 2         | 500   | 179  | 472   | 7401            | 1362  | 247     | 364   | 2806        | 730   |
| 196   | 513   | 4180         | 1793  | 41        | 73    | 196  | 513   | 7401            | 1362  | 162     | 333   | 2767        | 777   |
| 176   | 390   | 4180         | 1793  | 69        | 0     | 176  | 390   | 7235            | 1232  | 308     | 362   | 2697        | 716   |

**5.2 The mean per unit estimate, Ratio estimate and product estimate**

|                | Rabi Food Grain | Wheat  | Pea    | Sunflower | Rabi pulse | Rabi Cereals | Linseed |
|----------------|-----------------|--------|--------|-----------|------------|--------------|---------|
| $\sum X$       | 49414.9         | 27321  | 1247.9 | 191.996   | 21133      | 28782.95     | 1431    |
| $\sum y$       | 8918.98         | 11286  | 3145.9 | 1606.99   | 5502       | 11502.96     | 2546    |
| $\bar{x}$      | 7059.28         | 3903   | 178.28 | 27.428    | 3019       | 4111.85      | 204.42  |
| $\bar{y}$      | 1274.14         | 1612.2 | 449.42 | 229.57    | 786        | 1643.28      | 363.714 |
| $\bar{y}_R$    | 1289.50         | 1638.2 | 418.47 | .....     | 804.155    | 1620.82      | .....   |
| $\bar{y}_P$    | .....           | .....  | .....  | 225.44    | .....      | .....        | 319.38  |
| $\bar{y}_{AR}$ | 1287.28         | 1631.4 | 443.79 | .....     | 795.219    | 1627.544     | .....   |
| $\bar{y}_{GR}$ | 1287.27         | 1630.9 | 433.52 | .....     | 795.236    | 1627.515     | .....   |
| $\bar{y}_{HR}$ | 1287.26         | 1630.8 | 433.24 | .....     | 795.187    | 1627.482     | .....   |
| $\bar{y}_{AP}$ | .....           | .....  | .....  | 226.906   | .....      | .....        | 354.559 |
| $\bar{y}_{GP}$ | .....           | .....  | .....  | 226.90    | .....      | .....        | 354.082 |
| $\bar{y}_{HP}$ | .....           | .....  | .....  | 226.89    | .....      | .....        | 353.580 |



**Figure (5.2.1): Graphical representation of mean per unit estimate and ratio estimates for Rabi Food Grain, Wheat, Pea, Rabi Pulses, and Rabi Cereals**

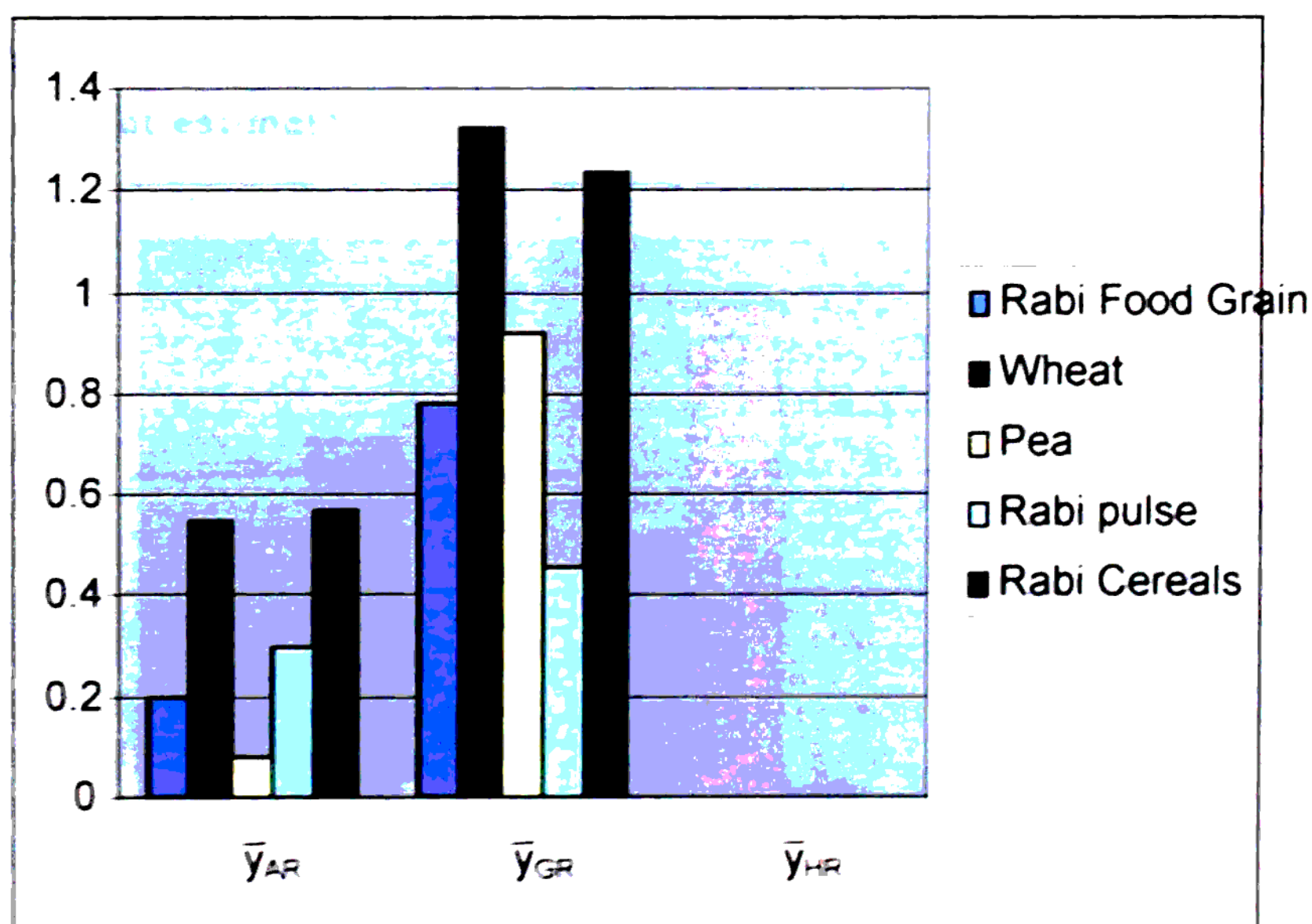


**Figure (5.2.2): Graphical representation of mean per unit estimate and, product estimates for Sun Flower and Linseed**

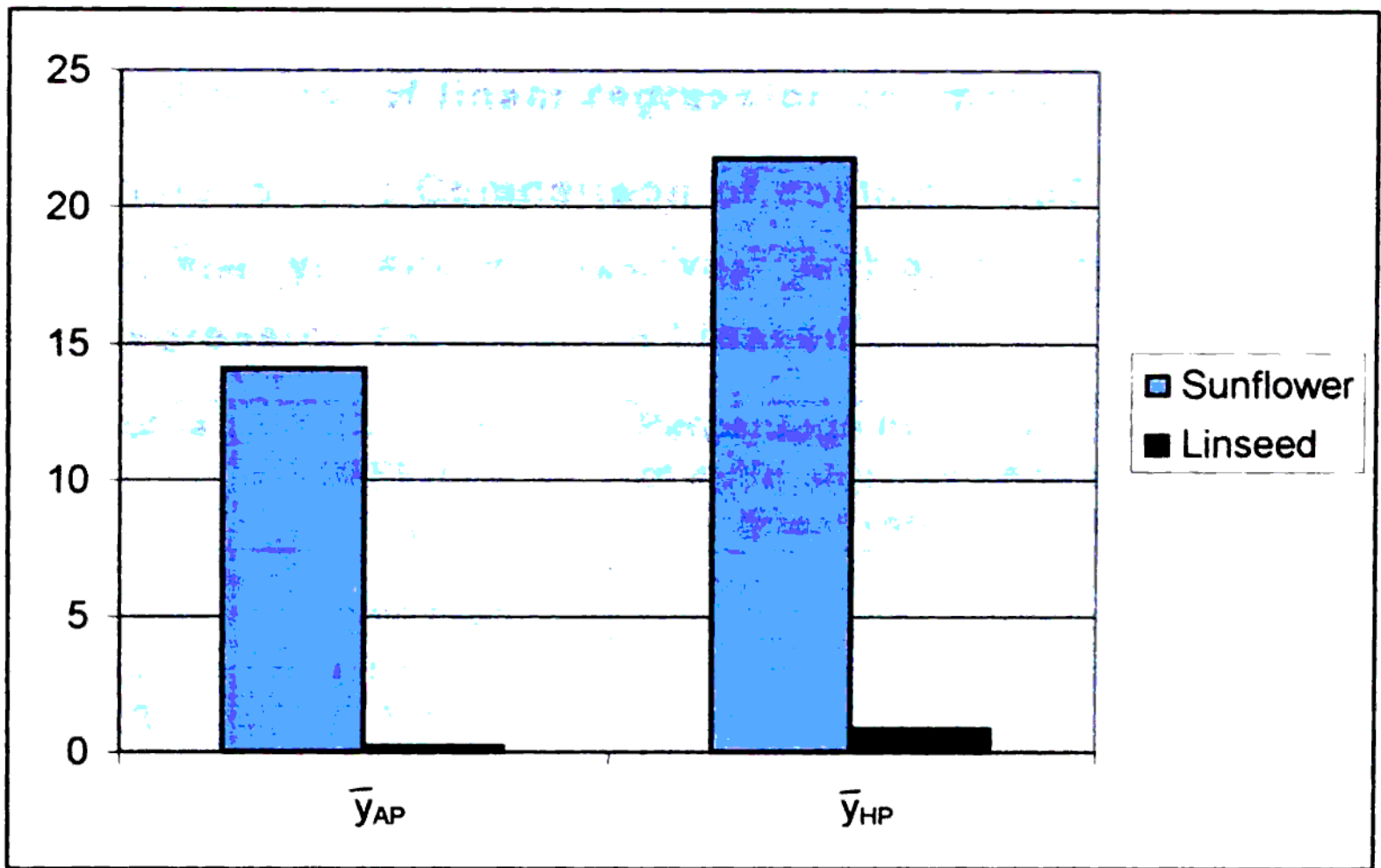
### 5.3 First order bias and optimum mean square error

**Table (5.3.1): First order bias and optimum mean square error in rabi food grain, wheat, Pea, Sunflower, Rabi pulses, Rabi Cereals, Linseed.**

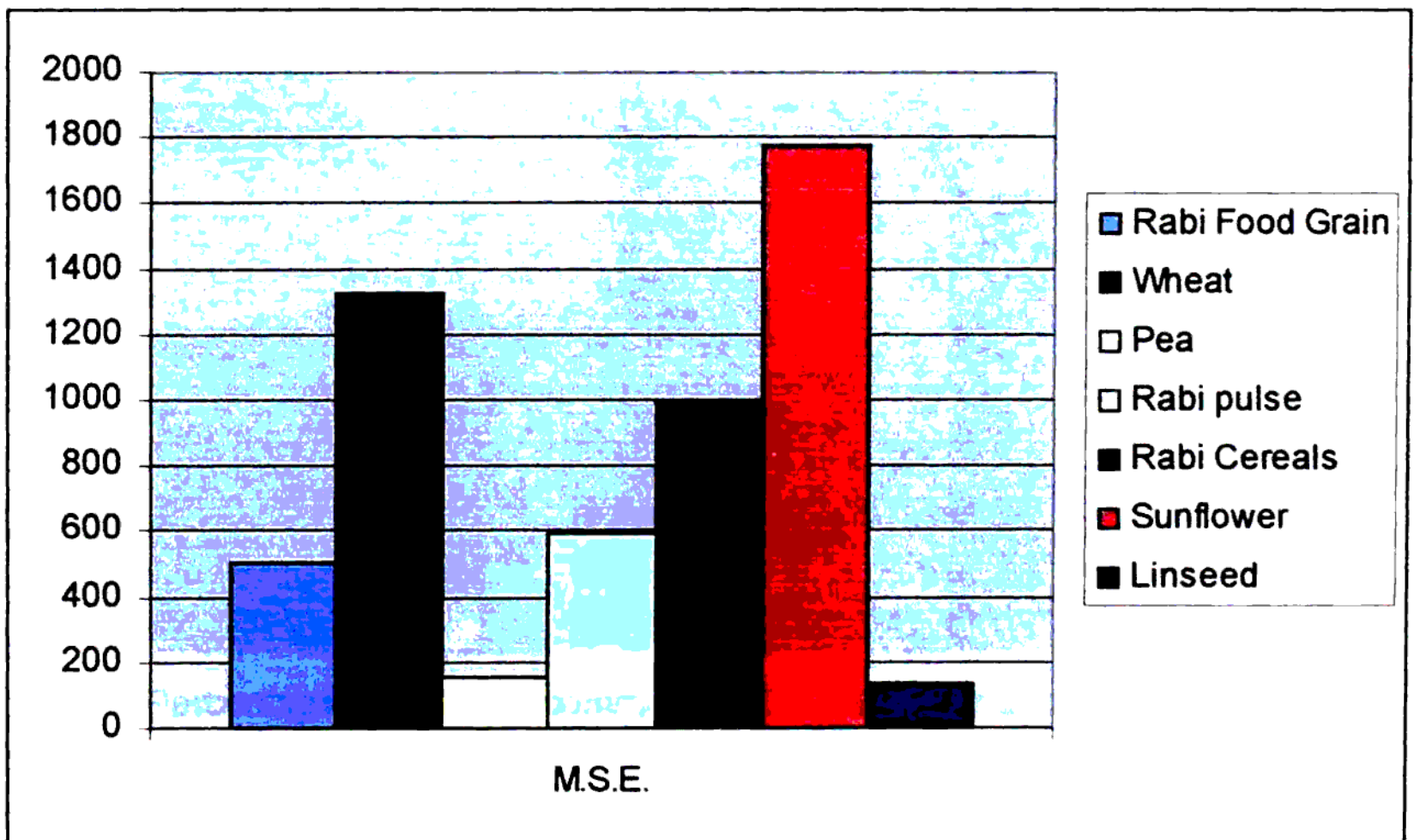
|                | Rabi Food Grain | Wheat  | Pea    | Sunflower | Rabi pulse | Rabi Cereals | Linseed |
|----------------|-----------------|--------|--------|-----------|------------|--------------|---------|
| $\bar{y}_{AR}$ | 0.1957          | 0.5488 | 0.0780 | .....     | 0.2999     | 0.56788      | .....   |
| $\bar{y}_{GR}$ | 0.7767          | 1.3182 | 0.9210 | .....     | 0.45732    | 1.23275      | .....   |
| $\bar{y}_{HR}$ | 0.0000          | 0.0000 | 0.0000 | .....     | 0.00000    | 0.0000       | .....   |
| $\bar{y}_{AP}$ | .....           | .....  | .....  | 14.0372   | .....      | .....        | 0.17437 |
| $\bar{y}_{HP}$ | .....           | .....  | .....  | 21.7665   | .....      | .....        | 0.8452  |
| MSE            | 501.55          | 1323.7 | 155.15 | 1776.191  | 598.039    | 987.683      | 133.58  |



**Figure (5.3.2): Graphical representation of first order bias of weighted mean (arithmetic mean, geometric mean, harmonic mean) of ratio estimator**



**Figure (5.3.2): Graphical representation of first order bias of weighted mean (arithmetic mean, harmonic mean) of product estimator**

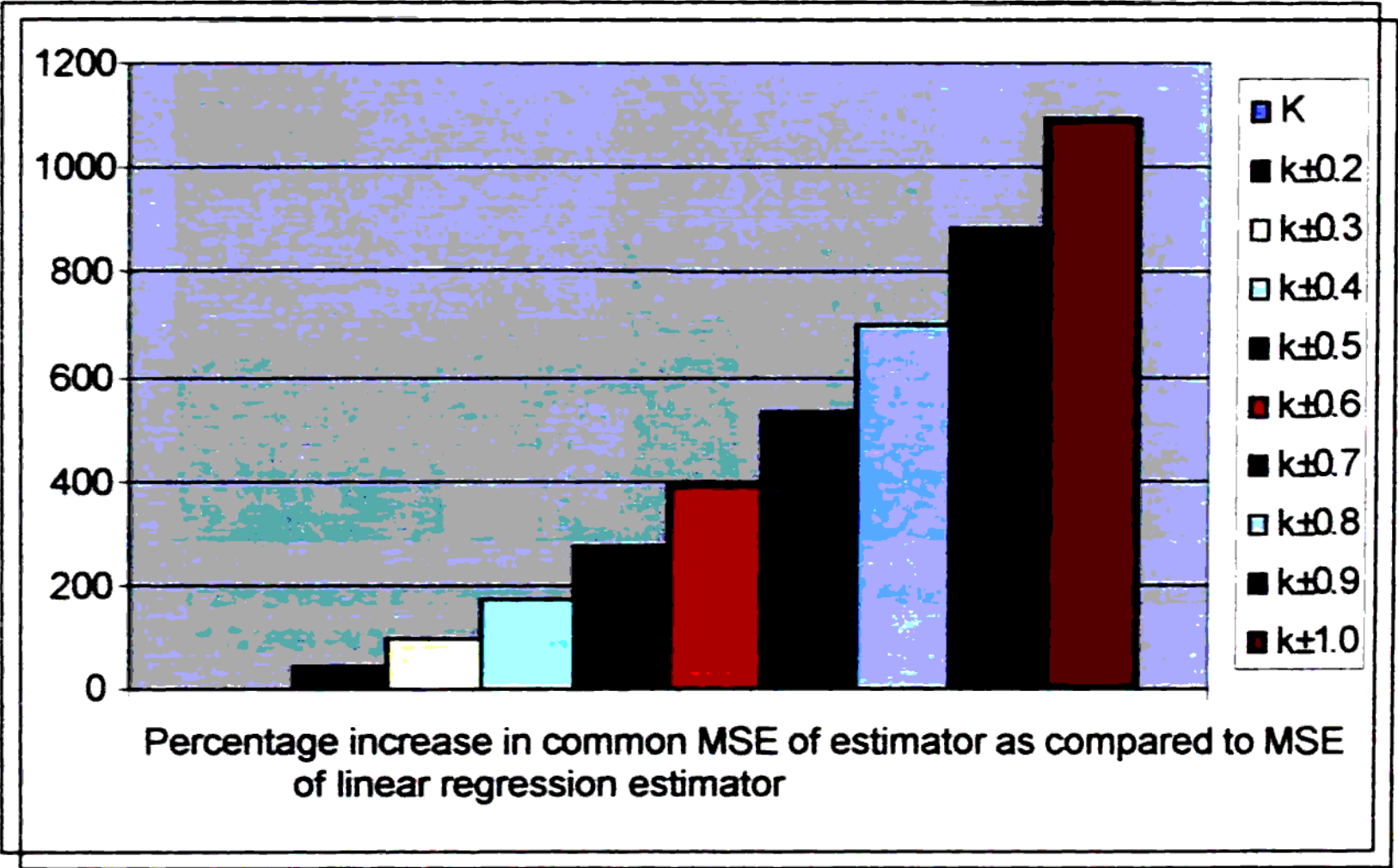


**Figure (5.3.3): Graphical representation of common MSE in Rabi Food Grain, Wheat, Pea, Sunflower, Rabi Pulses, Rabi Cereals and Linseed**

**5.4 Relative change in mean squarer error as compared to that of linear regression estimator**

**Table (5.4.1): Comparison of common MSE of estimators ( $\bar{Y}_R, \bar{Y}_{AR}, \bar{Y}_{GR}, \bar{Y}_{HR}$  and  $\bar{Y}_P, \bar{Y}_{AP}, \bar{Y}_{GP}, \bar{Y}_{HP}$ ) as compare to that of linear regression estimator in Linseed**

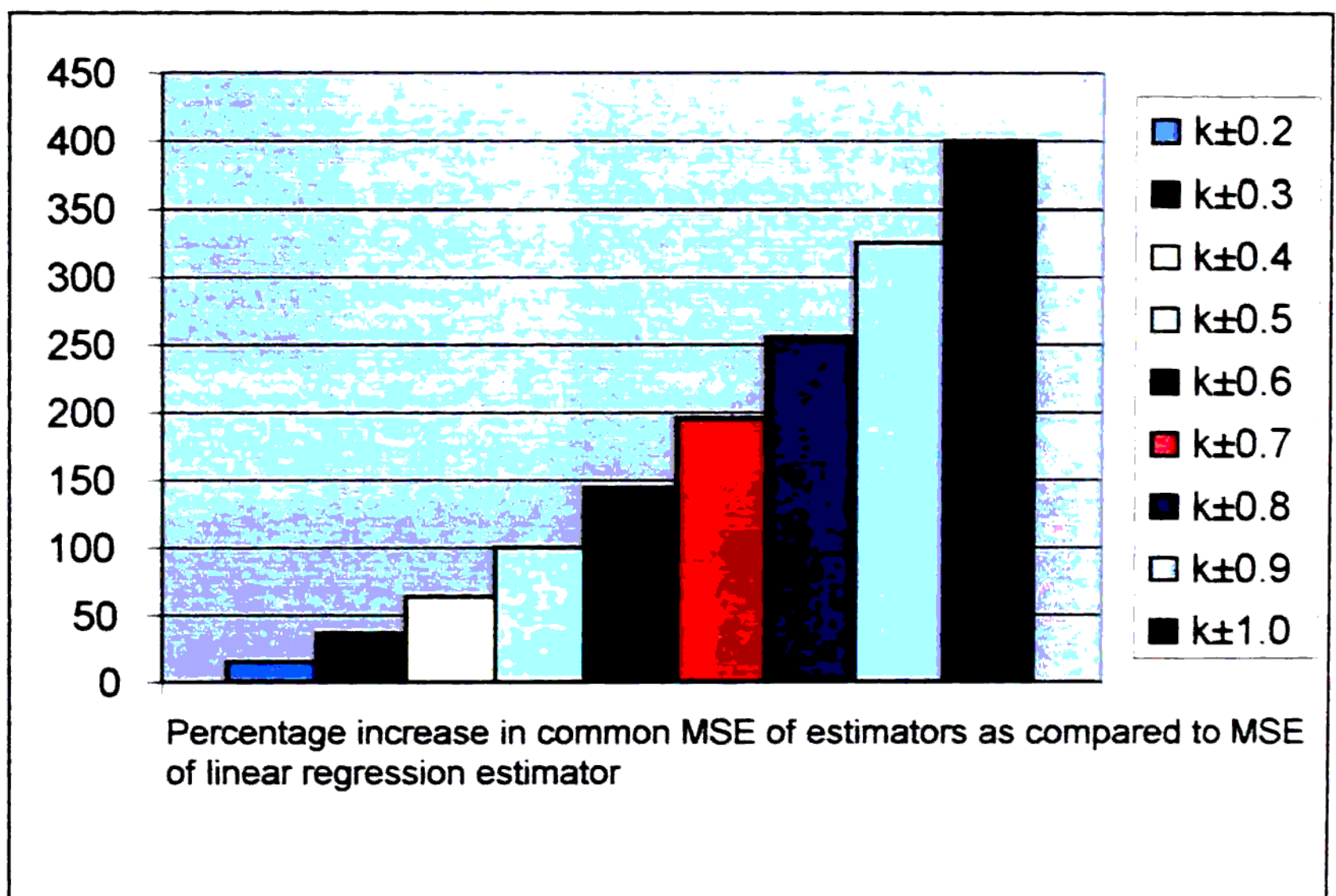
| Value of w | Common (MSE) $n/\bar{Y}^2$<br>$\bar{Y}_P$ | Percentage increase in common MSE of estimators as compared to MSE of linear regression estimator |
|------------|---|---|
| K          | 0.007395                                  | .....   |
| k±0.2      | 0.010622                                  | 43.63   |
| k±0.3      | 0.014654                                  | 98.17   |
| k±0.4      | 0.020300                                  | 174.50  |
| k±0.5      | 0.027559                                  | 272.67  |
| k±0.6      | 0.036431                                  | 392.64  |
| k±0.7      | 0.046917                                  | 534.4   |
| k±0.8      | 0.059015                                  | 698.08  |
| k±0.9      | 0.072727                                  | 883.461   |
| K±1.0      | 0.088051                                  | 1090.69   |



**Figure (5.4.1): Graphical representation of Comparison of common MSE of estimators as compared to that of linear regression estimator in Linseed**

**Table 5.4.2 Comparison of common MSE of estimators as compare to that of linear regression estimate in Rabi Food Grain**

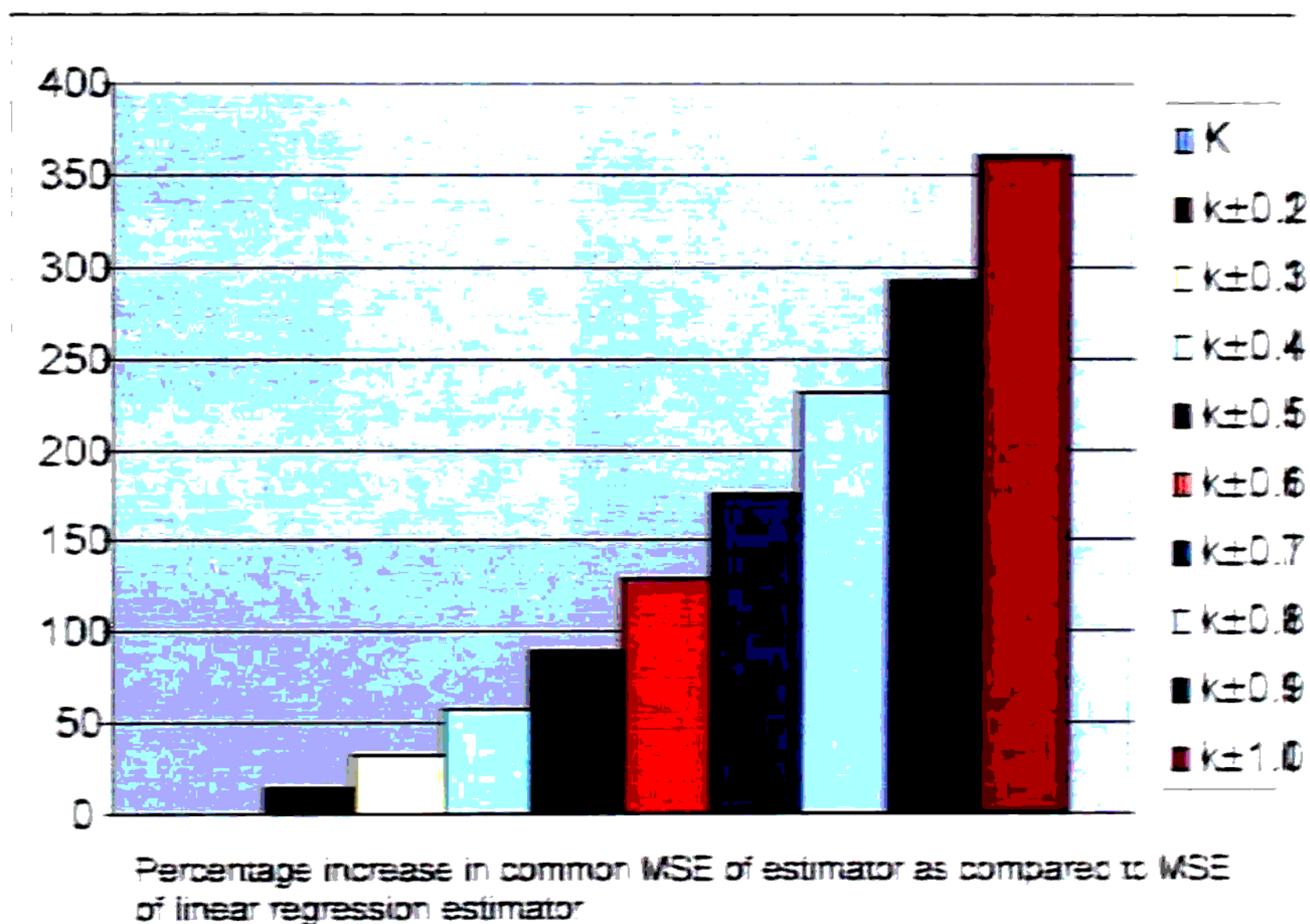
| Value of w | Common $(MSE)_n / \bar{Y}^2$ | Percentage increase in common MSE of estimators as compared to MSE of linear regression estimator |
|------------|------------------------------|---|
| K          | 0.002185                     | .....   |
| k±0.2      | 0.002535                     | 16  |
| k±0.3      | 0.002973                     | 36  |
| k±0.4      | 0.003586                     | 64.14   |
| k±0.5      | 0.004375                     | 100.2   |
| k±0.6      | 0.005339                     | 144.34  |
| k±0.7      | 0.006478                     | 196.47  |
| k±0.8      | 0.007792                     | 256.61  |
| k±0.9      | 0.009281                     | 324.75  |
| k±1.0      | 0.010940                     | 400.68  |



**Figure (5.4.2): Graphical representation of Comparison of common MSE of estimators as compared to that of linear regression estimator in Rabi Food Grain**

**Table (5.4.3): Comparison of common MSE of estimators as compare to that of linear regression estimate in Wheat**

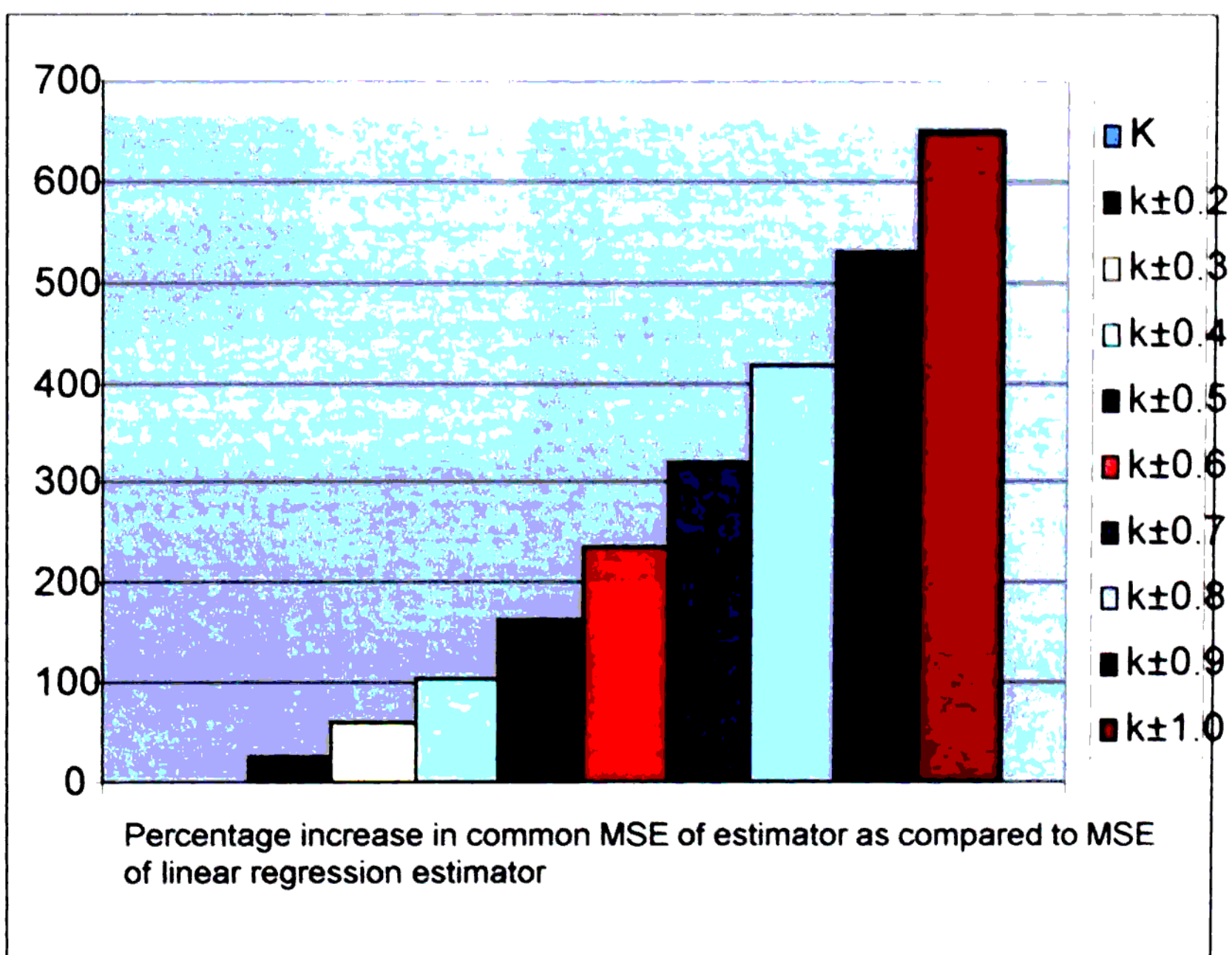
| Value of w | Common (MSE) <sub>n</sub> / $\overline{Y^2}$ / $\overline{Y_R}$ | Percentage increase in common MSE of estimators as compared to MSE of linear regression estimator |
|------------|---|---|
| K          | 0.003255  |   |
| k±0.2      | 0.003722  | 14.34   |
| k±0.3      | 0.004308  | 32.35   |
| k±0.4      | 0.005129  | 57.57   |
| k±0.5      | 0.006185  | 90.01   |
| k±0.6      | 0.007476  | 129.6   |
| k±0.7      | 0.009003  | 175.5   |
| k±0.8      | 0.010764  | 230.6   |
| k±0.9      | 0.012766  | 292   |
| k±1.0      | 0.014999  | 350.5   |



**Figure (5.4.3): Graphical representation of Comparison of common MSE of estimators as compared to that of linear regression estimator in Wheat**

**Table (5.4.4): Comparison of common MSE of estimators as compare to that of linear regression estimate in Pea**

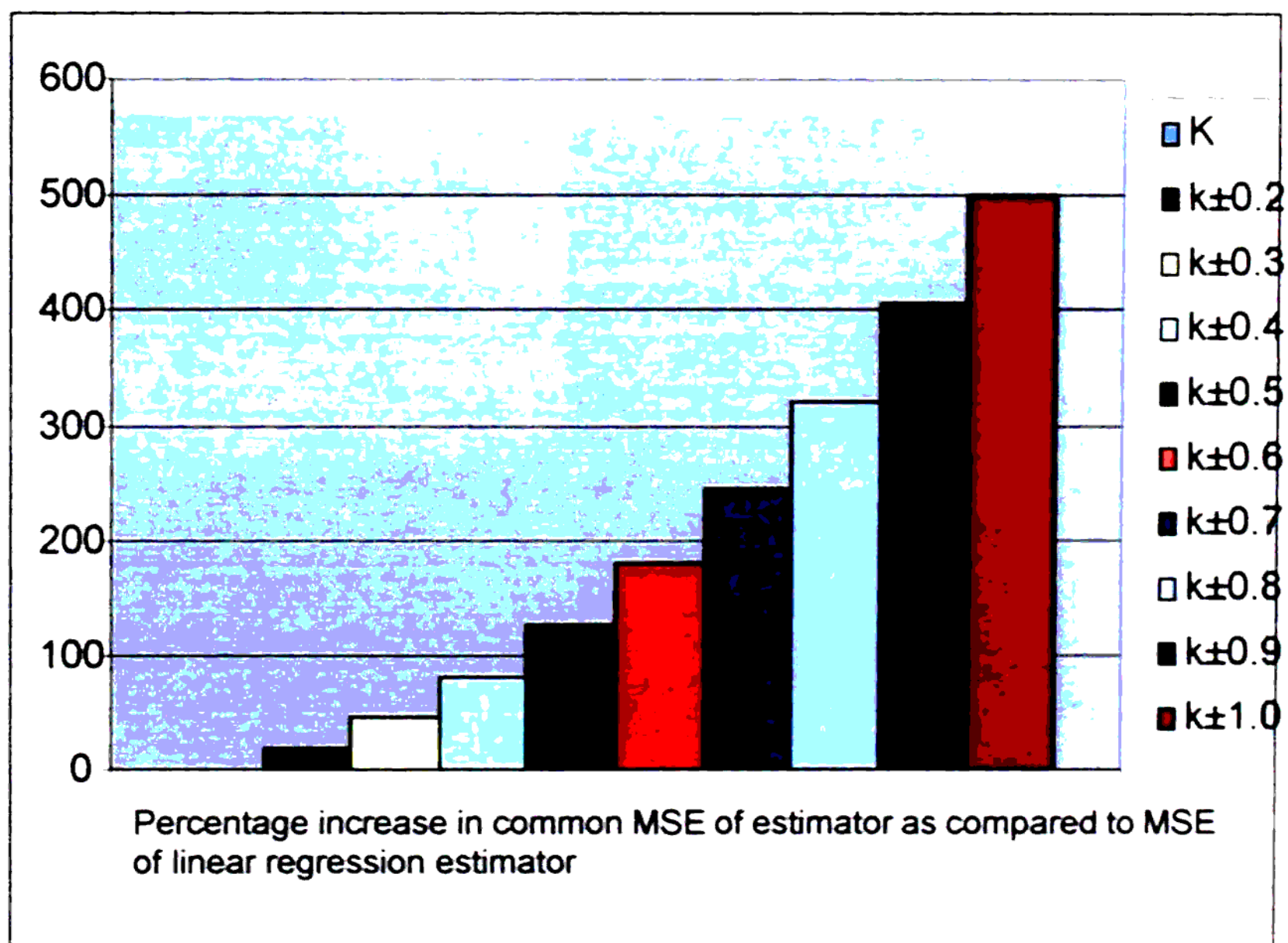
| Value of w | Common<br>(MSE) $n/\bar{Y}^2$<br>$\bar{Y}_R$ | Percentage increase in common MSE<br>of estimators as compared to MSE of<br>linear regression estimator |
|------------|--|---|
| K          | 0.006345                                     | .....   |
| k±0.2      | 0.007997                                     | 26  |
| k±0.3      | 0.01006                                      | 58.55   |
| k±0.4      | 0.01295                                      | 104.097   |
| k±0.5      | 0.01666                                      | 162.56  |
| k±0.6      | 0.02121                                      | 234.27  |
| k±0.7      | 0.02657                                      | 318.75  |
| k±0.8      | 0.03277                                      | 416.46  |
| k±0.9      | 0.03979                                      | 529.10  |
| k±1.0      | 0.04763                                      | 650.66  |



**Figure (5.4.4): Graphical representation of Comparison of common MSE of estimators as compared to that of linear regression estimator in Pea**

**Table (5.4.5): Comparison of common MSE of estimators as compare to that of linear regression estimate in Sunflower**

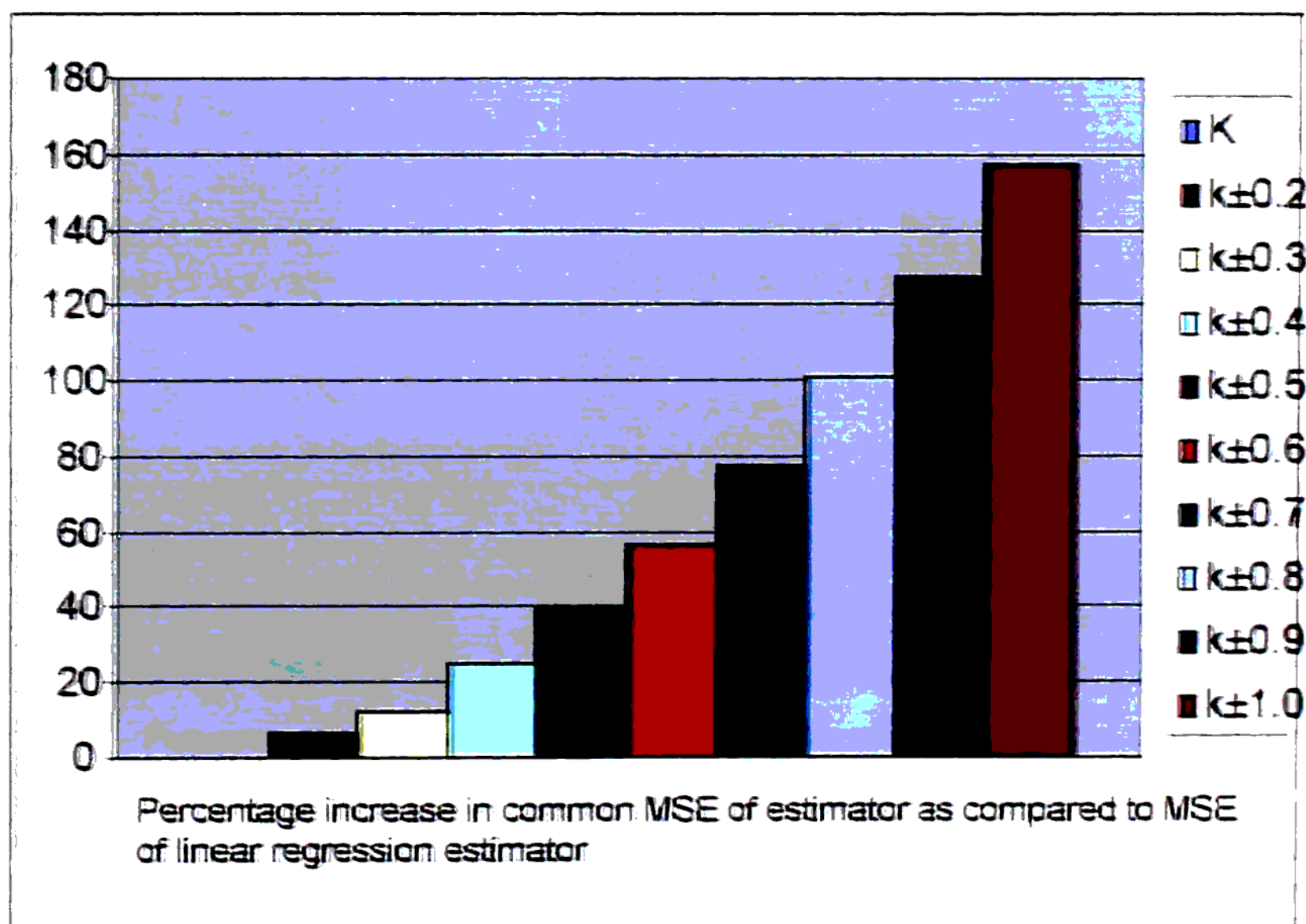
| Value of w | Common (MSE) $n/\bar{Y}^2$<br>$\bar{y}_p$ | Percentage increase in common MSE of estimators as compared to MSE of linear regression estimator |
|------------|---|---|
| K          | 0.17899                                   | .....   |
| k±0.2      | 0.2144                                    | 19.78   |
| k±0.3      | 0.25966                                   | 45.06   |
| k±0.4      | 0.3224                                    | 80.12   |
| k±0.5      | 0.40309                                   | 125.20  |
| k±0.6      | 0.50170                                   | 180.29  |
| k±0.7      | 0.6182                                    | 245.3   |
| k±0.8      | 0.75270                                   | 320.52  |
| k±0.9      | 0.9050                                    | 405.61  |
| k±1.0      | 1.0754                                    | 500.8   |



**Figure (5.4.5): Graphical representation of Comparison of common MSE of estimators as compared to that of linear regression estimator in Sunflower**

**Table (5.4.6): Comparison of MSE of estimator as compare to that of linear regression estimate in Rabi Pulses**

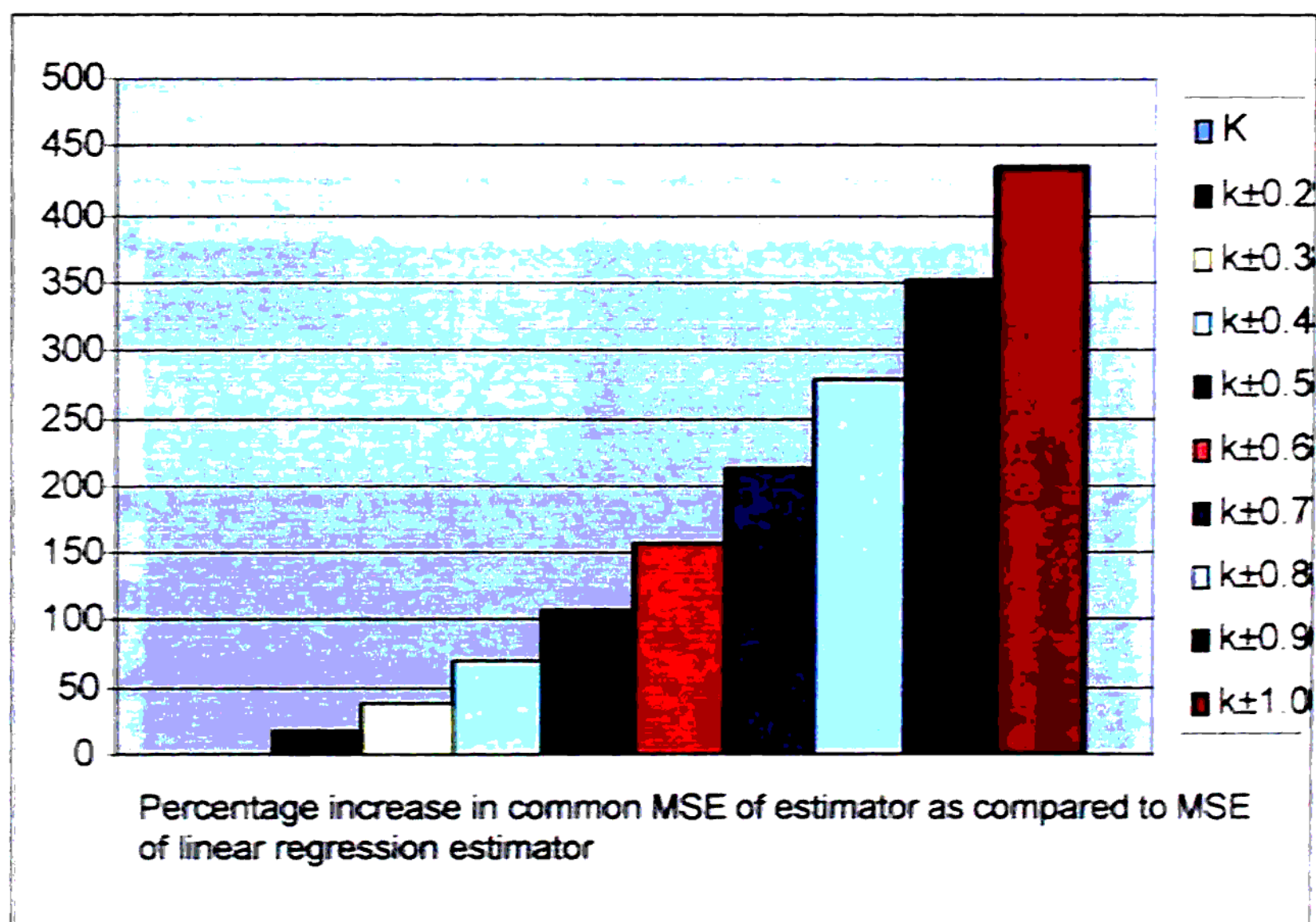
| Value of w | Common (MSE)n/ $\bar{Y}^2$ | Percentage increase in common MSE of estimator as compared to MSE of linear regression estimator |
|------------|----------------------------|--|
| K          | 0.006798                   | .....  |
| k±0.2      | 0.007226                   | 6.29   |
| k±0.3      | 0.007622                   | 12.12  |
| k±0.4      | 0.008512                   | 25.213   |
| k±0.5      | 0.009476                   | 39.39  |
| k±0.6      | 0.010654                   | 56.72  |
| k±0.7      | 0.012047                   | 77.21  |
| k±0.8      | 0.013654                   | 100.72   |
| k±0.9      | 0.01547                    | 127.56   |
| k±1.0      | 0.01751                    | 157.57   |



**Figure (5.4.6): Graphical representation of Comparison of common MSE of estimator as compared to that of linear regression estimator in Rabi Pulses**

**Table (5.4.7): Comparison of common MSE of estimator as compare to that of linear regression estimate in Rabi Cereal**

| Value of w | Common<br>(MSE) $n/\bar{Y}^2$<br>$\bar{Y}_R$ | Percentage increase in common MSE<br>of estimator as compared to MSE of<br>linear regression estimator |
|------------|--|--|
| K          | 0.002584                                     | .....  |
| k±0.2      | 0.003034                                     | 17.41  |
| k±0.3      | 0.0035961                                    | 39.16  |
| k±0.4      | 0.004382                                     | 69.58  |
| k±0.5      | 0.005393                                     | 108.70   |
| k±0.6      | 0.006629                                     | 156.54   |
| k±0.7      | 0.008090                                     | 213.08   |
| k±0.8      | 0.009775                                     | 278.28   |
| k±0.9      | 0.011686                                     | 352.2  |
| k±1.0      | 0.013820                                     | 434.8  |

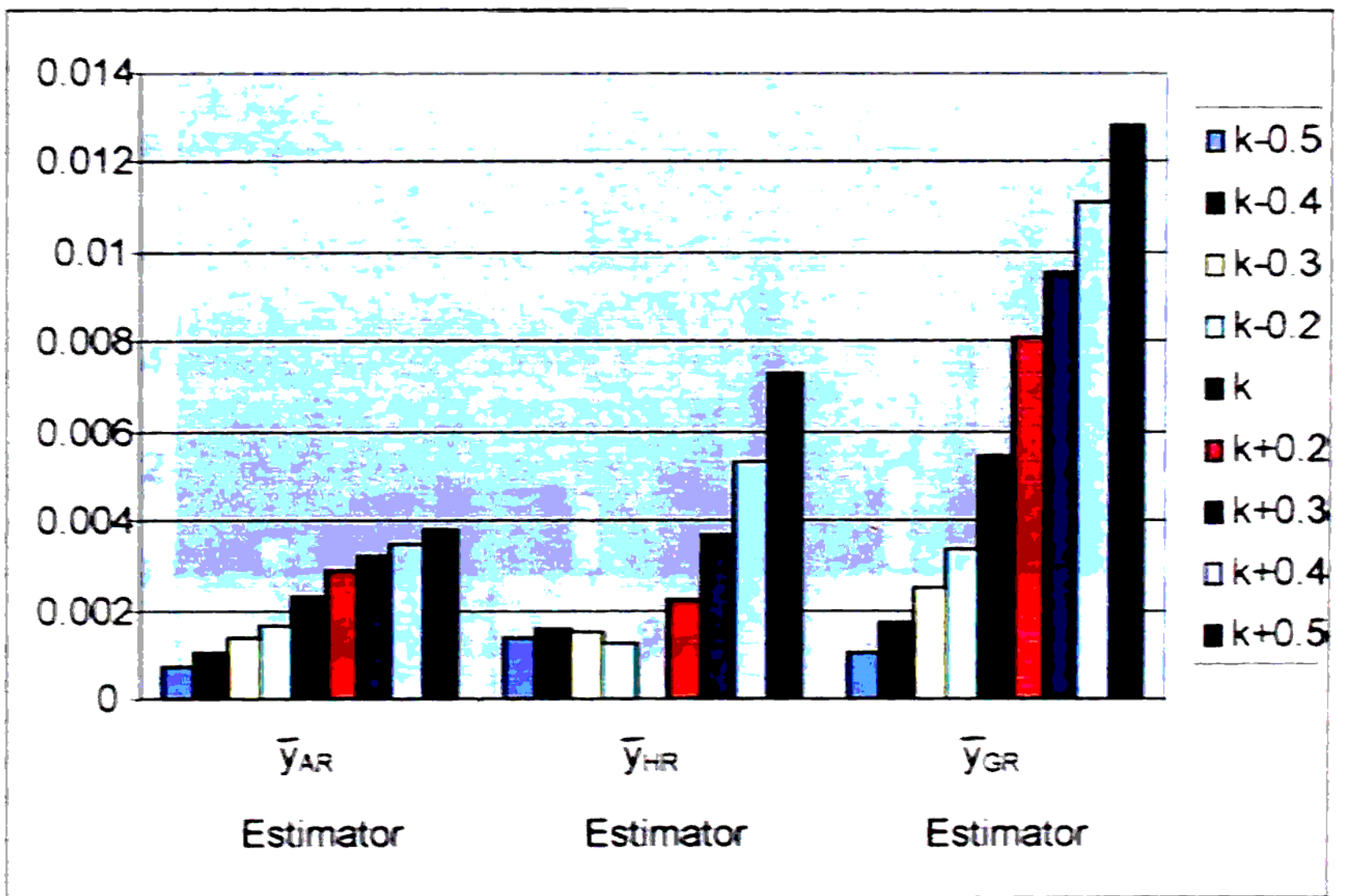


**Figure (5.4.7): Graphical representation of Comparison of common MSE of estimator as compared to that of linear regression estimator in Rabi Cereal**

**5.5 Comparison of Behaviour of relative  $n(\text{absolute bias of the estimator})/\bar{Y}$  for different weight ( $k-0.5$  to  $k+0.5$ )**

**Table (5.5.1): Behaviour of bias in Wheat for different weight ( $k-0.5$  to  $k+0.5$ )**

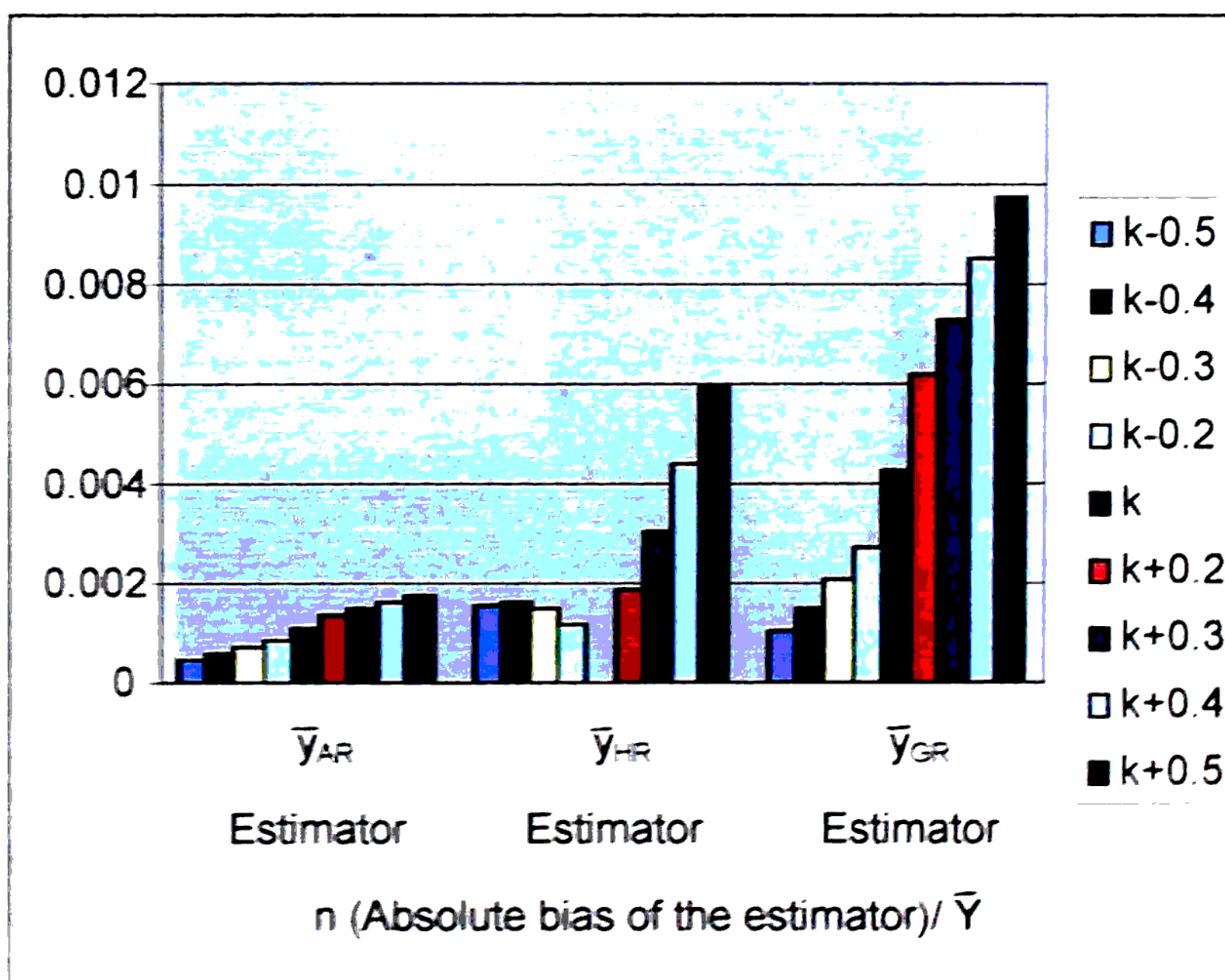
| Value of w | n (Absolute bias of the estimator)/ $\bar{Y}$ |                          |                          |
|------------|---|--------------------------|--------------------------|
|            | Estimator $\bar{Y}_{AR}$                      | Estimator $\bar{Y}_{HR}$ | Estimator $\bar{Y}_{GR}$ |
| k-0.5      | 0.0007324                                     | 0.001392                 | 0.0010624                |
| k-0.4      | 0.001041                                      | 0.001583                 | 0.0017087                |
| k-0.3      | 0.001350                                      | 0.001540                 | 0.00247249               |
| k-0.2      | 0.001659                                      | 0.001262                 | 0.00335379               |
| k          | 0.002277                                      | 0.000000                 | 0.00546889               |
| k+0.2      | 0.002895                                      | 0.002202                 | 0.00805401               |
| k+0.3      | 0.003204                                      | 0.003655                 | 0.00952283               |
| k+0.4      | 0.003513                                      | 0.005344                 | 0.01110916               |
| k+0.5      | 0.003822                                      | 0.007267                 | 0.0128129                |



**Figure (5.5.1): Graphical representation of Behaviour of relative  $n(\text{absolute bias of the estimator})/\bar{Y}$  for different weight ( $k-0.5$  to  $k+0.5$ ) in Wheat**

**Table (5.5.2): Behaviour of bias in Rabi Food Grain for different weight (k- 0.5 to k+0.5)**

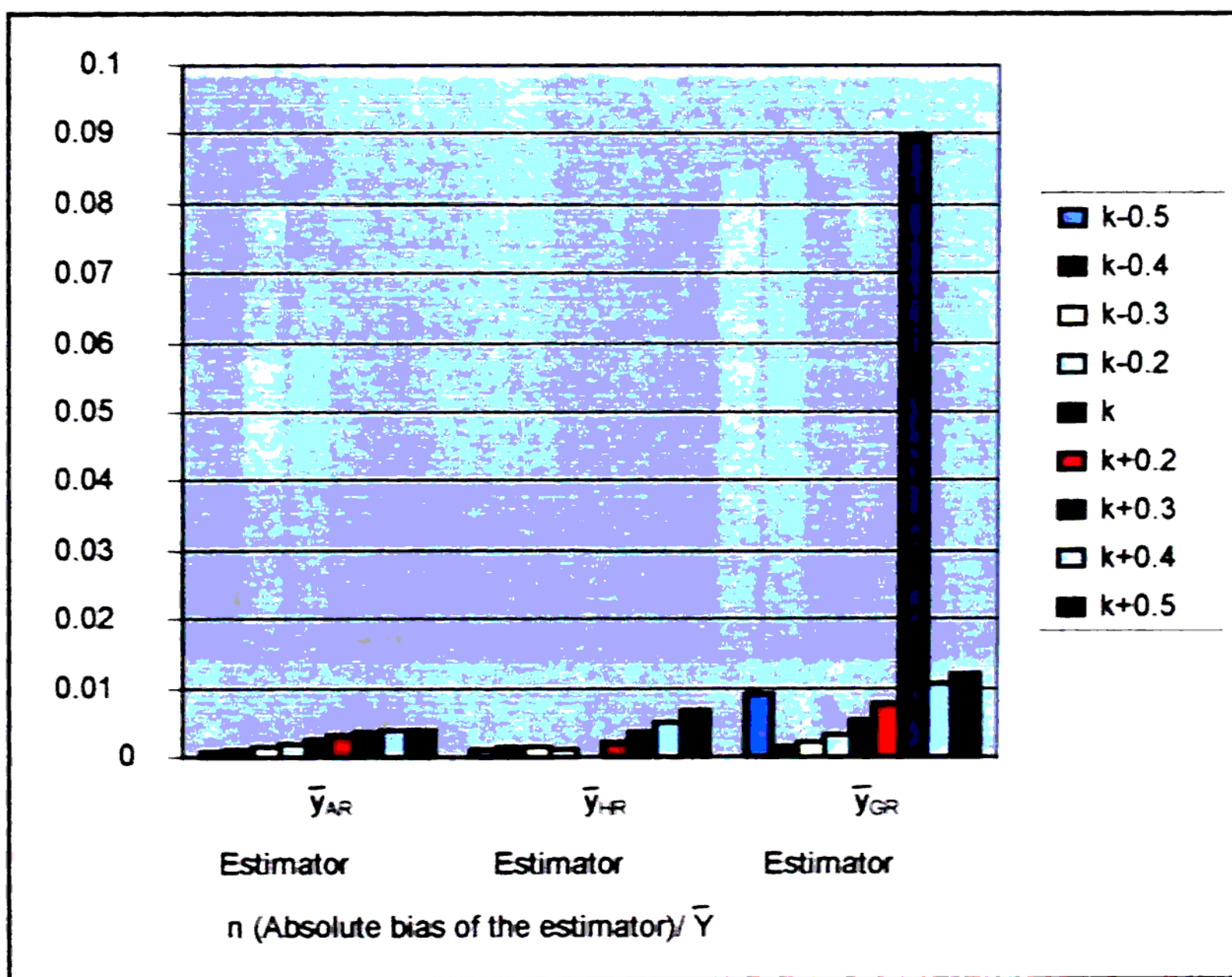
| Value of w | n (Absolute bias of the estimator)/ $\bar{Y}$ |                          |                          |
|------------|---|--------------------------|--------------------------|
|            | Estimator $\bar{Y}_{AR}$                      | Estimator $\bar{Y}_{HR}$ | Estimator $\bar{Y}_{GR}$ |
| k-0.5      | 0.0004494                                     | 0.001558                 | 0.00100403               |
| k-0.4      | 0.0005758                                     | 0.001597                 | 0.00148588               |
| k-0.3      | 0.0007021                                     | 0.001460                 | 0.00205534               |
| k-0.2      | 0.0008284                                     | 0.001149                 | 0.00271242               |
| k          | 0.001081                                      | 0.00000                  | 0.00428939               |
| k+0.2      | 0.001333                                      | 0.001849                 | 0.00621680               |
| k+0.3      | 0.001460                                      | 0.003037                 | 0.00731192               |
| k+0.4      | 0.001586                                      | 0.004400                 | 0.00849465               |
| k+0.5      | 0.0017128                                     | 0.005939                 | 0.00976499               |



**Figure (5.5.2): Graphical representation of Behaviour of relative n(absolute bias of the estimator)/  $\bar{Y}$  for different weight (k- 0.5 to k+0.5) in Rabi Food Grain**

**Table (5.5.3): Behaviour of bias in Rabi Cereals for different weight (k-0.5 to k+0.5)**

| Value of w | n (Absolute bias of the estimator)/ $\bar{Y}$ |                          |                          |
|------------|---|--------------------------|--------------------------|
|            | Estimator $\bar{Y}_{AR}$                      | Estimator $\bar{Y}_{HR}$ | Estimator $\bar{Y}_{GR}$ |
| k-0.5      | 0.0006748                                     | 0.001126                 | 0.0090086                |
| k-0.4      | 0.001011                                      | 0.0013509                | 0.0015188                |
| k-0.3      | 0.001347                                      | 0.0013503                | 0.0022491                |
| k-0.2      | 0.001684                                      | 0.0011249                | 0.003091.8               |
| k          | 0.002356                                      | 0.00000                  | 0.0051143                |
| k+0.2      | 0.003029                                      | 0.002023                 | 0.0075862                |
| k+0.3      | 0.003366                                      | 0.003372                 | 0.0899078                |
| k+0.4      | 0.003702                                      | 0.004946                 | 0.0105076                |
| k+0.5      | 0.004038                                      | 0.006744                 | 0.0121368                |

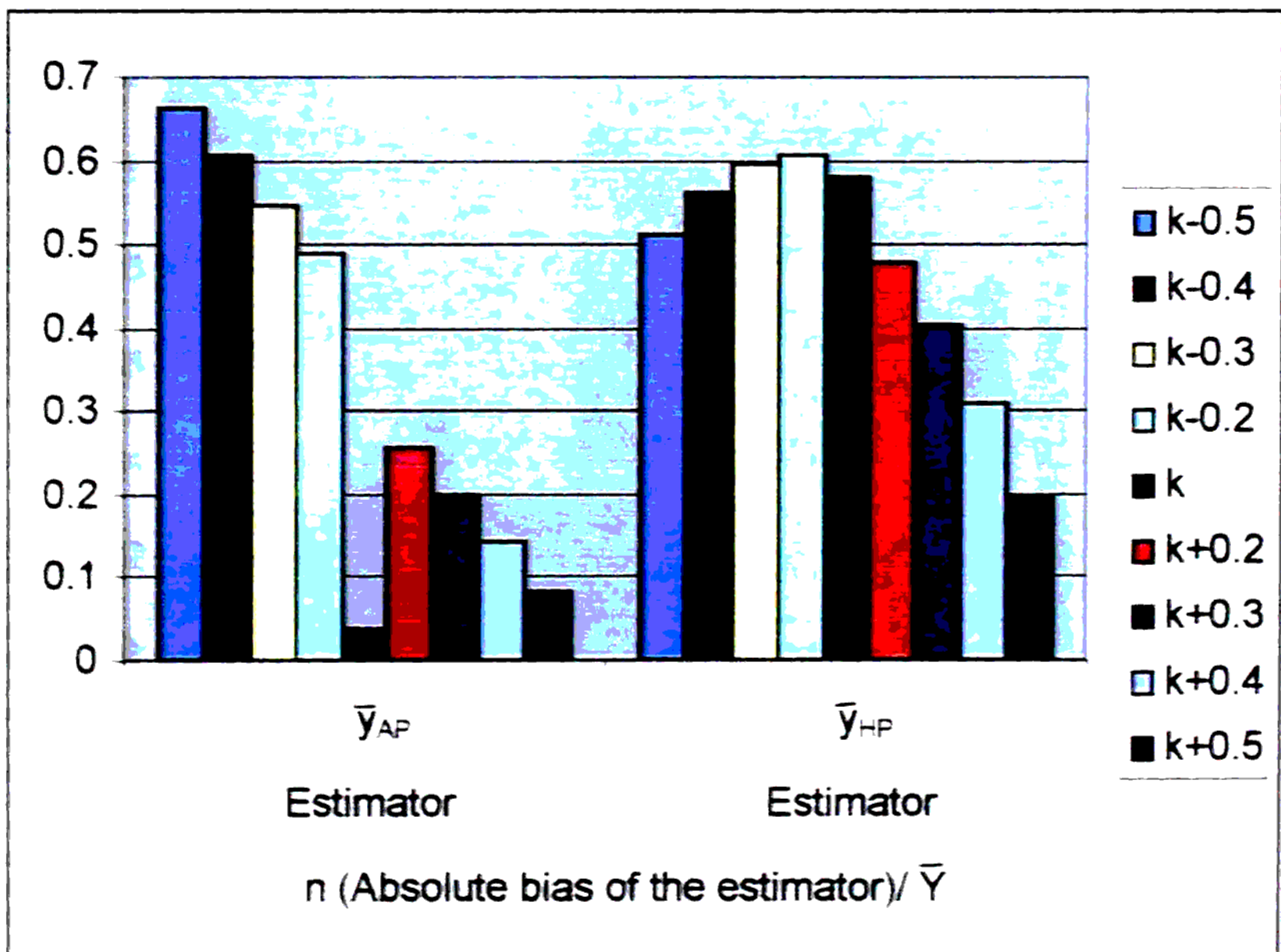


**Figure (5.5.3): Graphical representation of Behaviour of relative n(absolute bias of the estimator)/  $\bar{Y}$  for different weight (k-0.5 to k+0.5) in Rabi Cereals**



**Table (5.5.4): Behaviour of bias in Sunflower for different weight (k-0.5 to k+0.5)**

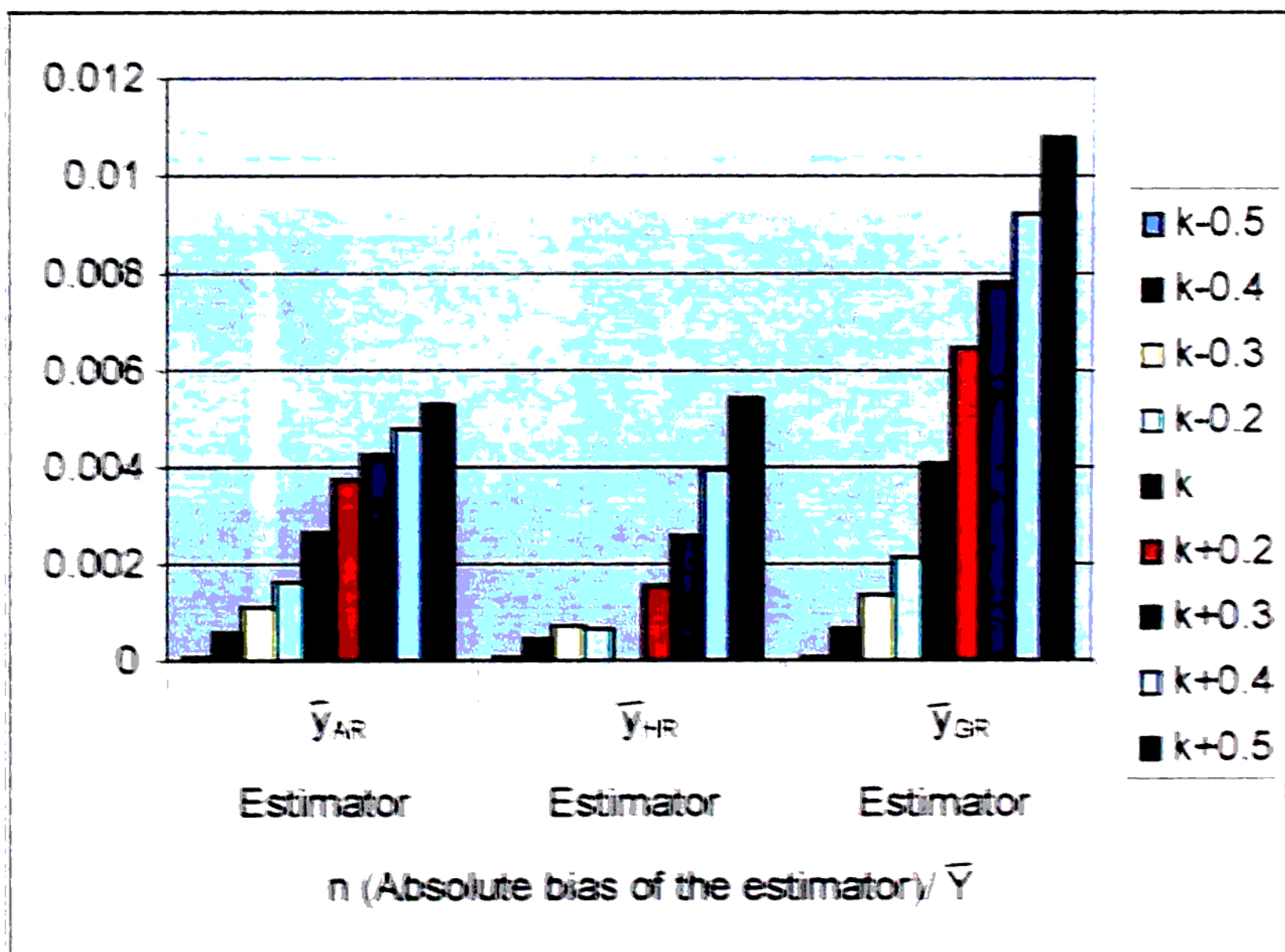
| Value of w | n (Absolute bias of the estimator)/ $\bar{Y}$ |                          |
|------------|---|--------------------------|
|            | Estimator $\bar{Y}_{AP}$                      | Estimator $\bar{Y}_{HP}$ |
| k-0.5      | 0.66187                                       | 0.51316                  |
| k-0.4      | 0.604064                                      | 0.562007                 |
| k-0.3      | 0.54625                                       | 0.592925                 |
| k-0.2      | 0.48844                                       | 0.6059151                |
| k          | 0.037282                                      | 0.578107                 |
| k+0.2      | 0.25720                                       | 0.478586                 |
| k+0.3      | 0.19938                                       | 0.401932                 |
| k+0.4      | 0.14157                                       | 0.30735                  |
| k+0.5      | 0.08376                                       | 0.1948391                |



**Figure (5.5.4): Graphical representation of Behaviour of relative n(absolute bias of the estimator)/  $\bar{Y}$  for different weight (k-0.5 to k+0.5) in Sunflower**

**Table (5.5.5): Behaviour of bias in Rabi Pulses for different weight (k-0.5 to k+0.5)**

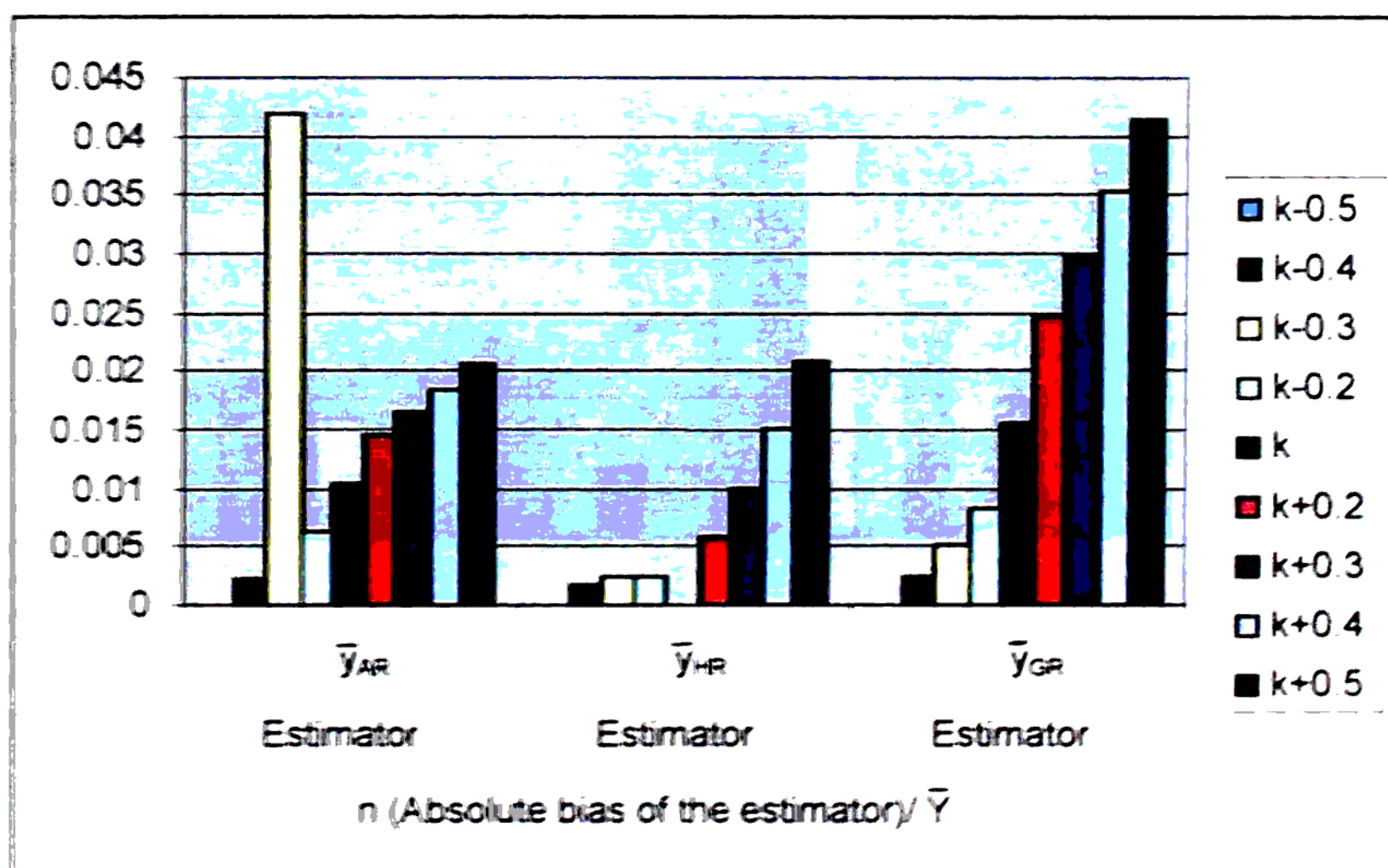
| Value of w | n (Absolute bias of the estimator)/ $\bar{Y}$ |                          |                          |
|------------|---|--------------------------|--------------------------|
|            | Estimator $\bar{Y}_{AR}$                      | Estimator $\bar{Y}_{HR}$ | Estimator $\bar{Y}_{GR}$ |
| k-0.5      | 0.000061                                      | 0.0000630                | 0.0000623                |
| k-0.4      | 0.000584                                      | 0.0004789                | 0.0006515                |
| k-0.3      | 0.001107                                      | 0.0006805                | 0.0013478                |
| k-0.2      | 0.001630                                      | 0.0006679                | 0.0021512                |
| k          | 0.002676                                      | 0.0000000                | 0.0040794                |
| k+0.2      | 0.003722                                      | 0.0015249                | 0.0064361                |
| k+0.3      | 0.004245                                      | 0.0026087                | 0.0077751                |
| k+0.4      | 0.004768                                      | 0.0039068                | 0.0092213                |
| k+0.5      | 0.005291                                      | 0.0054192                | 0.0107740                |



**Figure (5.5.5): Graphical representation of Behaviour of relative n (absolute bias of the estimator)/  $\bar{Y}$  for different weight (k-0.5 to k+0.5) in Rabi Pulses**

**Table (5.5.6): Behaviour of bias in Pea for different weight (k-0.5 to k+0.5)**

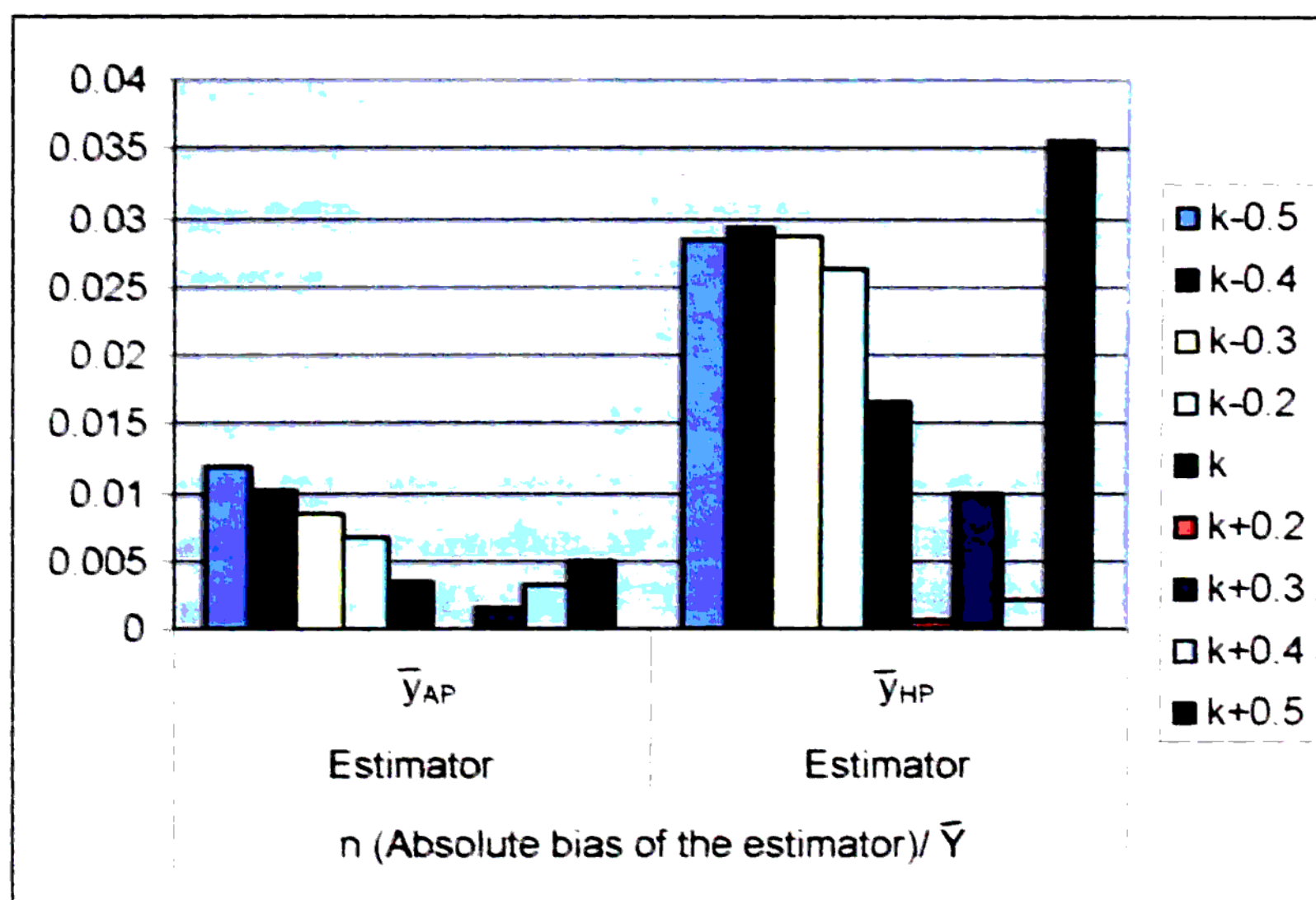
| Value of w | n (Absolute bias of the estimator)/ $\bar{Y}$ |                          |                          |
|------------|---|--------------------------|--------------------------|
|            | Estimator $\bar{Y}_{AR}$                      | Estimator $\bar{Y}_{HR}$ | Estimator $\bar{Y}_{GR}$ |
| k-0.5      | 0.0001001                                     | 0.00010116               | 0.000100665              |
| k-0.4      | 0.002144                                      | 0.0017325                | 0.00237162               |
| k-0.3      | 0.04188                                       | 0.0025381                | 0.005055494              |
| k-0.2      | 0.006233                                      | 0.0025178                | 0.008152262              |
| k          | 0.01032                                       | 0.000000                 | 0.015584                 |
| k+0.2      | 0.01441                                       | 0.0058210                | 0.0246683                |
| k+0.3      | 0.01645                                       | 0.0099703                | 0.029829638              |
| k+0.4      | 0.0184  | 0.01494                  | 0.03540382               |
| k+0.5      | 0.02054                                       | 0.02074                  | 0.0413909                |



**Figure (5.5.6): Graphical representation of Behaviour of relative n(absolute bias of the estimator)/  $\bar{Y}$  for different weight (k-0.5 to k+0.5) in Pea**

**Table (5.5.7): Behaviour of bias in Linseed for different weight (k-0.5 to k+0.5)**

| Value of w | n (Absolute bias of the estimator)/ $\bar{Y}$ |                          |
|------------|---|--------------------------|
|            | Estimator $\bar{Y}_{AP}$                      | Estimator $\bar{Y}_{HP}$ |
| k-0.5      | 0.011752                                      | 0.02848                  |
| k-0.4      | 0.010088                                      | 0.02934                  |
| k-0.3      | 0.008424                                      | 0.02858                  |
| k-0.2      | 0.006760                                      | 0.02621                  |
| k          | 0.003432                                      | 0.01663                  |
| k+0.2      | 0.000104                                      | 0.00060                  |
| k+0.3      | 0.001559                                      | 0.00982                  |
| k+0.4      | 0.003223                                      | 0.00218                  |
| k+0.5      | 0.004886                                      | 0.03553                  |



**Figure (5.5.7): Graphical representation of Behaviour of relative n(Absolute bias of the estimator)/  $\bar{Y}$  for different weight (k-0.5 to k+0.5) in Linseed**

## DISCUSSION

The first order bias and common mean square error in optimum case has been worked out and the result is presented in table 4. In this table (4) we seen that in case of positive correlation the estimator  $\bar{y}_{HR}$  which is weighted harmonic mean of mean per unit estimator and ratio estimator become unbiased and should be preferred over all the other estimators under consideration. Value of common mean square error in first order approximation is same as optimum mean square error. This optimum mean square error is same as that of linear regression estimator, so in all these cases, all these estimators are equally efficient as far as first order mean square error is considered.

It is clear from above study that in all seven populations the increase in first order mean square error of the estimators under comparison is grater than 10% for deviation of value of  $w$  from its optimum value up to extent of  $\pm 0.5$ . Considering this, in order to study the behavior of bias of these estimator the value of  $w$  have been taken in the interval  $(k-0.5, k+0.5)$ .

It is also clear from the seven tables (5-5) that  $\bar{y}_{HR}$  is behaving consistently, as far as first order bias is concerned, in the sense that, with increase in the margin of the optimum value of  $w$  and its non optimum value, in either direction the absolute bias increases. The other four estimators do not follow this pattern. The same result also founded by Naik, V D and Gupta, P.C. (1991) in an empirical study of 5 natural populations

CHAPTER – VI

**SUMMARY, CONCLUSION AND  
SUGGESTION**

## SUMMARY CONCLUSION AND SUGGESTION FOR FURTHER WORK

### 6.1 Summary

Apart from ratio and product estimator for estimating population mean or total, a number of estimators had been proposed by Naik, V.D. and Gupta, P.C. (1991). This makes use of auxiliary (Apriori) information. It has been found rather difficult to make theoretical comparisons among the goodness of these estimators. In present study an attempt has been made to compare some of these estimators, using 15 years (1990-2005) live data on area and yield of Rabi and Kharif crops in Madhya Pradesh. [Source of data - Agricultural statistics published by Directorate of Agriculture, (M.P.)].

First we have considered data on 35 crops for testing the significance of correlation coefficient between two characteristics under study. Only those crops (Wheat, Rabi Cereals, Sunflower, Pea, and Rabi Food Grain, Linseed and Rabi Pulses) which have significant correlation between two characteristics under study (say area and yield) is taken for study purpose. Considering these crops, a sample of 7 years from 15 years using simple random sampling with replacement plan has been drawn. For sample selection purpose Tippett (1927) random number table has been used.

Weighted arithmetic mean weighted harmonic mean and weighted geometric mean of mean per unit estimator and ratio / product estimates has been worked out. From this it has conclude that, if auxiliary character X and character under study Y have positive correlation, then the weighted arithmetic mean of mean per unit estimator and ratio estimator, weighted harmonic mean and weighted geometric mean of mean per unit estimator ratio

estimators are found to give equal amount of estimate and if auxiliary character X and character under study Y have negative correlation, then the weighted arithmetic mean of mean per unit estimator and product estimator, weighted harmonic mean & weighted geometric mean of mean per unit estimator product estimators are found to give equal amount of estimate .

The first order bias and common mean square error in optimum case has been worked out and the result is presented in table 4. In this table it can be seen that in case of positive correlation the estimator  $\bar{y}_{HR}$ , which is weighted harmonic mean of mean per unit estimator and ratio estimator become unbiased and should be preferred over all the other estimators under consideration. Value of common mean square error in first order approximation is same as optimum mean square error. This optimum mean square error is same as that of linear regression estimator, so in all these cases, all these estimators are equally efficient as far as first order mean square error is considered.

It is clear from present study that in all seven populations the increase in first order mean square error of the estimators under comparison as compared to first order mean square error is grater than 10% for deviation of value of w from its optimum value up to extent of  $\pm 0.5$ . Considering this, in order to study the behavior of bias of these estimator the value of w have been taken in the interval  $(k-0.5, k+0.5)$ .

It is also clear from the tables (5.5) that  $\bar{y}_{HR}$  is following consistent pattern, as far as first order bias is concerned, in the sense that, with increase in the margin of the optimum value of w and its non optimum value, in either direction the absolute bias increases. The other four estimators do not follow this pattern.

estimators are found to give equal amount of estimate and if auxiliary character X and character under study Y have negative correlation, then the weighted arithmetic mean of mean per unit estimator and product estimator, weighted harmonic mean & weighted geometric mean of mean per unit estimator product estimators are found to give equal amount of estimate .

The first order bias and common mean square error in optimum case has been worked out and the result is presented in table 4. In this table it can be seen that in case of positive correlation the estimator  $\bar{y}_{HR}$ , which is weighted harmonic mean of mean per unit estimator and ratio estimator become unbiased and should be preferred over all the other estimators under consideration. Value of common mean square error in first order approximation is same as optimum mean square error. This optimum mean square error is same as that of linear regression estimator, so in all these cases, all these estimators are equally efficient as far as first order mean square error is considered.

It is clear from present study that in all seven populations the increase in first order mean square error of the estimators under comparison as compared to first order mean square error is grater than 10% for deviation of value of w from its optimum value up to extent of  $\pm 0.5$ . Considering this, in order to study the behavior of bias of these estimator the value of w have been taken in the interval  $(k-0.5, k+0.5)$ .

It is also clear from the tables (5.5) that  $\bar{y}_{HR}$  is following consistent pattern, as far as first order bias is concerned, in the sense that, with increase in the margin of the optimum value of w and its non optimum value, in either direction the absolute bias increases. The other four estimators do not follow this pattern.

## 6.2 Conclusion

The first order biases and MSE's of the estimators ( $\bar{y}_R$ ,  $\bar{y}_{AR}$ ,  $\bar{y}_{GR}$ , and  $\bar{y}_{HR}$ ) in case of positive correlation between two characteristics (X,Y) under study were worked out through numerical illustration. The MSE's of all these estimators were obtained equivalent. In optimum case, the MSE's of these estimators happened to be equivalent to that of regression estimator  $\bar{y}_{lr} = \bar{y}_n + b_{yx}(\bar{X}_N - \bar{X}_n)$ . The estimator  $\bar{y}_{HR}$  was found unbiased and hence this estimator must be preferred over all other estimators as far as the unbiasedness property of the estimators is considered for comparing them.

It was found that in all the seven populations under study, the increases in first order MSE's of all the estimators under consideration was greater than 10% of deviation of the value of weight (w) from its optimum values ( $w_0$ ) up to extent of margin of  $\pm 0.5$ . It was also observed that the amount of absolute bias ( $\bar{y}_{HR}$ ) increased in either directions of the optimum value of weight ( $w_0$ ), but other four estimators did not follow this pattern.

### **6.3 Suggestions for further work**

The present study has been done under simple random sampling strategies with replacement (SRSWR), it is known that simple random sampling without replacement (SRSWOR) is better than the SRSWR strategies in the sense that SRSWOR gives:

- 1 Better representative sample to the population.
- 2 There is no chance of repetition of the same sampling unit to be including in the sample to get better estimate of the population parameters.
- 3 More efficient (precise) estimate of the population parameter is obtained in case of using SRSWOR than that obtained in case of SRSWR.

Hence further worker in the field of sampling theory may derive such type of results (say bias and mean square error) for the estimators considering in this study. The derived results may be compared through numerical illustration based on some suitable secondary data taken from some reliable sources.

CHAPTER – VII

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# APPENDIX

## APPENDIX 1

**1.1 Area and yield of major kharif crops in M.P. State (Area: 000'Ha, Yield: Kg. / Ha.)**

| crop→<br>Years<br>↓ | Paddy |       | Jowar |       | Miaz |       | Bajra |       |
|---------------------|-------|-------|-------|-------|------|-------|-------|-------|
|                     | Area  | Yield | Area  | Yield | Area | Yield | Area  | Yield |
| 1990-91             | 1556  | 922   | 1624  | 904   | 778  | 1447  | 173   | 883   |
| 1991-92             | 1559  | 628   | 1361  | 728   | 777  | 953   | 158   | 734   |
| 1992-93             | 1573  | 754   | 1397  | 1094  | 808  | 1591  | 157   | 948   |
| 1993-94             | 1566  | 859   | 1262  | 986   | 804  | 1483  | 152   | 829   |
| 1994-95             | 1612  | 905   | 1022  | 670   | 765  | 994   | 142   | 856   |
| 1995-96             | 1672  | 423   | 976   | 848   | 763  | 1091  | 134   | 878   |
| 1996-97             | 1644  | 819   | 901   | 859   | 755  | 1091  | 139   | 978   |
| 1997-98             | 1656  | 742   | 826   | 851   | 769  | 1334  | 142   | 1088  |
| 1998-99             | 1672  | 892   | 745   | 968   | 760  | 1457  | 146   | 1179  |
| 1999-00             | 1740  | 1059  | 674   | 784   | 139  | 1586  | 801   | 1008  |
| 2000-01             | 1708  | 605   | 636   | 717   | 840  | 1459  | 165   | 1246  |
| 2001-02             | 1777  | 1005  | 637   | 903   | 854  | 1984  | 163   | 1265  |
| 2002-03             | 1681  | 646   | 652   | 921   | 860  | 1751  | 169   | 744   |
| 2003-04             | 1719  | 1074  | 783   | 1219  | 910  | 2068  | 202   | 1399  |
| 2004-05             | 1623  | 759   | 657   | 958   | 896  | 1406  | 176   | 1363  |

| Crop →<br>Years<br>↓ | Kodo kutki |       | Other Cereals |       | Kharif Cereals |       | Tur  |       |
|----------------------|------------|-------|---------------|-------|----------------|-------|------|-------|
|                      | Area       | Yield | Area          | Yield | Area           | Yield | Area | Yield |
| 1990-91              | 631        | 261   | 130           | 392   | 4892           | 899   | 401  | 970   |
| 1991-92              | 585        | 217   | 124           | 218   | 4564           | 653   | 383  | 735   |
| 1992-93              | 569        | 223   | 115           | 313   | 4619           | 933   | 375  | 928   |
| 1993-94              | 553        | 284   | 108           | 333   | 4445           | 923   | 384  | 938   |
| 1994-95              | 527        | 250   | 96            | 323   | 4164           | 766   | 317  | 814   |
| 1995-96              | 509        | 234   | 39            | 769   | 4093           | 809   | 335  | 771   |
| 1996-97              | 500        | 276   | 84            | 321   | 4023           | 808   | 334  | 839   |
| 1997-98              | 481        | 227   | 77            | 325   | 3951           | 822   | 323  | 705   |
| 1998-99              | 471        | 278   | 73            | 342   | 3867           | 923   | 321  | 920   |
| 1999-00              | 458        | 279   | 72            | 361   | 3884           | 989   | 311  | 870   |
| 2000-01              | 421        | 149   | 55            | 296   | 3825           | 770   | 313  | 668   |
| 2001-02              | 404        | 232   | 51            | 353   | 3886           | 1099  | 305  | 818   |
| 2002-03              | 381        | 200   | 46            | 289   | 3789           | 883   | 304  | 614   |
| 2003-04              | 366        | 295   | 43            | 395   | 4023           | 1237  | 315  | 809   |
| 2004-05              | 342        | 251   | 37            | 385   | 3731           | 909   | 327  | 782   |

| crop→      | Urad |       | Moong |       | Kulthi |       | Kharif Pulses |       |
|------------|------|-------|-------|-------|--------|-------|---------------|-------|
|            | Area | Yield | Area  | Yield | Area   | Yield | Area          | Yield |
| Years<br>↓ |      |       |       |       |        |       |               |       |
| 1990-91    | 506  | 292   | 138   | 308   | 63     | 293   | 1117          | 537   |
| 1991-92    | 449  | 258   | 121   | 260   | 63     | 196   | 1026          | 417   |
| 1992-93    | 433  | 314   | 128   | 349   | 57     | 170   | 1007          | 507   |
| 1993-94    | 433  | 318   | 121   | 348   | 59     | 289   | 1009          | 555   |
| 1994-95    | 373  | 300   | 106   | 305   | 57     | 287   | 867           | 495   |
| 1995-96    | 366  | 352   | 103   | 330   | 50     | 273   | 864           | 506   |
| 1996-97    | 400  | 361   | 102   | 351   | 50     | 313   | 897           | 532   |
| 1997-98    | 424  | 373   | 100   | 347   | 46     | 286   | 899           | 484   |
| 1998-99    | 420  | 340   | 94    | 340   | 44     | 265   | 885           | 545   |
| 1999-00    | 426  | 312   | 90    | 322   | 41     | 193   | 872           | 507   |
| 2000-01    | 414  | 249   | 88    | 239   | 37     | 172   | 857           | 401   |
| 2001-02    | 443  | 361   | 83    | 328   | 36     | 239   | 872           | 515   |
| 2002-03    | 521  | 279   | 83    | 259   | 33     | 232   | 947           | 388   |
| 2003-04    | 613  | 367   | 89    | 341   | 31     | 309   | 1053          | 498   |
| 2004-05    | 557  | 361   | 86    | 312   | 31     | 261   | 1006          | 493   |

| Crop →     | Kharif. Food Grains |       | Groundnut |       | Soybean |       | Sesamum |       |
|------------|---------------------|-------|-----------|-------|---------|-------|---------|-------|
|            | Area                | Yield | Area      | Yield | Area    | Yield | Area    | Yield |
| Years<br>↓ |                     |       |           |       |         |       |         |       |
| 1990-91    | 6009                | 832   | 282       | 770   | 2147    | 1016  | 210     | 237   |
| 1991-92    | 5590                | 609   | 243       | 705   | 2643    | 790   | 189     | 165   |
| 1992-93    | 5626                | 857   | 221       | 1144  | 3042    | 851   | 189     | 252   |
| 1993-94    | 5454                | 855   | 240       | 990   | 3384    | 1055  | 206     | 301   |
| 1994-95    | 5031                | 719   | 236       | 799   | 3205    | 890   | 165     | 224   |
| 1995-96    | 4957                | 756   | 221       | 1034  | 3822    | 1011  | 156     | 265   |
| 1996-97    | 4920                | 758   | 223       | 1000  | 4114    | 949   | 152     | 278   |
| 1997-98    | 4850                | 759   | 222       | 1008  | 4400    | 1089  | 145     | 230   |
| 1998-99    | 4752                | 852   | 217       | 1077  | 4541    | 1016  | 138     | 264   |
| 1999-00    | 4756                | 901   | 224       | 992   | 4440    | 1068  | 137     | 230   |
| 2000-01    | 4682                | 703   | 215       | 1053  | 4475    | 767   | 144     | 281   |
| 2001-02    | 4758                | 992   | 217       | 1116  | 4450    | 840   | 132     | 304   |
| 2002-03    | 4736                | 784   | 208       | 619   | 4191    | 638   | 127     | 230   |
| 2003-04    | 5076                | 1084  | 218       | 1155  | 4212    | 1106  | 144     | 351   |
| 2004-05    | 4737                | 821   | 209       | 1154  | 4485    | 836   | 135     | 396   |

| Crop →  | Niger |       | Castor |       | Kharif Oil Seeds |       | Cotton |       |
|---------|-------|-------|--------|-------|------------------|-------|--------|-------|
|         | Area  | Yield | Area   | Yield | Area             | Yield | Area   | Yield |
| Years ↓ |       |       |        |       |                  |       |        |       |
| 1990-91 | 143   | 237   | 3      | 353   | 2785             | 892   | 608    | 333   |
| 1991-92 | 130   | 110   | 1      | 250   | 3206             | 719   | 560    | 225   |
| 1992-93 | 129   | 174   | 7      | 371   | 3588             | 813   | 468    | 375   |
| 1993-94 | 140   | 236   | 5      | 302   | 3975             | 982   | 489    | 435   |
| 1994-95 | 136   | 216   | 4      | 318   | 3746             | 830   | 477    | 363   |
| 1995-96 | 134   | 224   | 2      | 272   | 4335             | 961   | 514    | 420   |
| 1996-97 | 130   | 219   | 3      | 345   | 4622             | 908   | 520    | 426   |
| 1997-98 | 126   | 155   | 3      | 220   | 4896             | 1035  | 515    | 501   |
| 1998-99 | 120   | 204   | 3      | 345   | 5022             | 978   | 497    | 436   |
| 1999-00 | 121   | 225   | 2      | 333   | 4926             | 752   | 488    | 442   |
| 2000-01 | 108   | 158   | 3      | 248   | 4945             | 752   | 498    | 244   |
| 2001-02 | 110   | 223   | 2      | 323   | 4912             | 823   | 541    | 369   |
| 2002-03 | 103   | 169   | 1      | 343   | 4631             | 752   | 559    | 351   |
| 2003-04 | 103   | 229   | 2      | 376   | 4680             | 1064  | 564    | 566   |
| 2004-05 | 111   | 235   | 2      | 378   | 4943             | 824   | 576    | 555   |

**1.2 Area and yield of major Rabi crops in M.P. State (Area: 000'Ha, Yield: Kg. / Ha.)**

| Crop →  | Wheat |       | Barley |       | Other Cereals |       | Rabi Cereals |       |
|---------|-------|-------|--------|-------|---------------|-------|--------------|-------|
|         | Area  | Yield | Area   | Yield | Area          | Yield | Area         | Yield |
| 1990-91 | 3738  | 1536  | 96     | 1065  | 13            | 615   | 3847         | 1521  |
| 1991-92 | 3458  | 1465  | 80     | 1173  | 6             | 667   | 3544         | 1457  |
| 1992-93 | 3589  | 1410  | 80     | 928   | 13            | 100   | 3682         | 1428  |
| 1993-94 | 4053  | 1647  | 80     | 1266  | 14            | 857   | 4147         | 1637  |
| 1994-95 | 4096  | 1777  | 82     | 1357  | 10            | 500   | 4188         | 1766  |
| 1995-96 | 3925  | 1744  | 87     | 1262  | 7             | 714   | 4019         | 1663  |
| 1996-97 | 4235  | 1818  | 79     | 1113  | 9             | 667   | 4323         | 1803  |
| 1997-98 | 4502  | 1655  | 86     | 1234  | 7             | 714   | 4595         | 1581  |
| 1998-99 | 4575  | 1883  | 87     | 1160  | 8             | 882   | 4670         | 1791  |
| 1999-00 | 4669  | 1938  | 85     | 1192  | 9             | 778   | 4763         | 1847  |
| 2000-01 | 3311  | 1535  | 83     | 1117  | 2             | 717   | 3396         | 1461  |
| 2001-02 | 3704  | 1691  | 84     | 1288  | 4             | 903   | 3792         | 1612  |
| 2002-03 | 3381  | 1520  | 81     | 1257  | 5             | 755   | 3467         | 1451  |
| 2003-04 | 4091  | 1879  | 84     | 1462  | 5             | 1000  | 4180         | 1793  |
| 2004-05 | 4136  | 1811  | 83     | 1253  | 3             | 719   | 4222         | 1725  |

| Crop →  | Gram |       | Peas |       | Lentil |       | Teora |       |
|---------|------|-------|------|-------|--------|-------|-------|-------|
|         | Area | Yield | Area | Yield | Area   | Yield | Area  | Yield |
| 1990-91 | 2261 | 792   | 117  | 383   | 322    | 497   | 63    | 495   |
| 1991-92 | 1951 | 814   | 110  | 335   | 335    | 468   | 65    | 631   |
| 1992-93 | 2166 | 764   | 113  | 354   | 363    | 478   | 67    | 655   |
| 1993-94 | 2161 | 852   | 132  | 384   | 383    | 487   | 72    | 888   |
| 1994-95 | 2543 | 926   | 164  | 352   | 413    | 488   | 79    | 777   |
| 1995-96 | 2465 | 766   | 160  | 388   | 483    | 463   | 75    | 596   |
| 1996-97 | 2328 | 934   | 176  | 390   | 494    | 486   | 69    | 820   |
| 1997-98 | 2414 | 981   | 175  | 410   | 463    | 439   | 63    | 246   |
| 1998-99 | 2580 | 975   | 187  | 435   | 497    | 484   | 60    | 896   |
| 1999-00 | 2575 | 985   | 196  | 513   | 507    | 539   | 63    | 1106  |
| 2000-01 | 1978 | 820   | 169  | 421   | 489    | 422   | 51    | 586   |
| 2001-02 | 2554 | 944   | 179  | 472   | 500    | 481   | 53    | 717   |
| 2002-03 | 2471 | 694   | 193  | 401   | 467    | 387   | 49    | 687   |
| 2003-04 | 2791 | 927   | 200  | 485   | 479    | 501   | 51    | 755   |
| 2004-05 | 2746 | 929   | 219  | 483   | 498    | 498   | 40    | 685   |

| Crop →  | Other pulses |       | Rabi Pulses |       | Rabi Food Grains |       | Rape/ Mustard |       |
|---------|--------------|-------|-------------|-------|------------------|-------|---------------|-------|
|         | Area         | Yield | Area        | Yield | Area             | Yield | Area          | Yield |
| 1990-91 | 19           | 421   | 2806        | 730   | 6653             | 1188  | 511           | 902   |
| 1991-92 | 19           | 737   | 2480        | 741   | 6024             | 1162  | 551           | 851   |
| 1992-93 | 19           | 316   | 2728        | 703   | 6410             | 1120  | 593           | 770   |
| 1993-94 | 19           | 368   | 2767        | 777   | 6914             | 1293  | 640           | 890   |
| 1994-95 | 14           | 714   | 3213        | 835   | 7401             | 1362  | 611           | 816   |
| 1995-96 | 33           | 333   | 3216        | 693   | 7235             | 1232  | 641           | 860   |
| 1996-97 | 15           | 267   | 3082        | 825   | 7405             | 1396  | 682           | 942   |
| 1997-98 | 2            | 1500  | 3117        | 849   | 7712             | 1285  | 653           | 604   |
| 1998-99 | 13           | 209   | 3337        | 867   | 8007             | 1406  | 592           | 918   |
| 1999-00 | 13           | 357   | 3354        | 890   | 8117             | 1451  | 626           | 998   |
| 2000-01 | 10           | 300   | 2697        | 716   | 6093             | 1131  | 419           | 773   |
| 2001-02 | 12           | 444   | 3298        | 841   | 7090             | 1254  | 506           | 909   |
| 2002-03 | 10           | 340   | 3190        | 630   | 6657             | 1057  | 369           | 650   |
| 2003-04 | 11           | 364   | 3532        | 839   | 7712             | 1356  | 537           | 1083  |
| 2004-05 | 11           | 371   | 3514        | 835   | 7736             | 1321  | 682           | 989   |

| Crop →  | Linseed |       | Sunflower and Others |       | Rabi Oil Seeds |       | Sugarcane |       |
|---------|---------|-------|----------------------|-------|----------------|-------|-----------|-------|
|         | Area    | Yield | Area                 | Yield | Area           | Yield | Area      | Yield |
| 1990-91 | 319     | 305   | 58                   | 0     | 888            | 651   | 38        | 3553  |
| 1991-92 | 256     | 322   | 64                   | 109   | 871            | 641   | 43        | 3618  |
| 1992-93 | 276     | 326   | 69                   | 0     | 938            | 582   | 36        | 3439  |
| 1993-94 | 310     | 347   | 59                   | 136   | 1009           | 680   | 27        | 4383  |
| 1994-95 | 308     | 362   | 44                   | 114   | 963            | 638   | 35        | 3829  |
| 1995-96 | 279     | 327   | 41                   | 73    | 961            | 674   | 45        | 4062  |
| 1996-97 | 265     | 374   | 52                   | 96    | 999            | 748   | 42        | 3970  |
| 1997-98 | 256     | 308   | 8                    | 250   | 917            | 518   | 39        | 3956  |
| 1998-99 | 247     | 364   | 6                    | 306   | 845            | 753   | 38        | 4090  |
| 1999-00 | 231     | 402   | 7                    | 286   | 864            | 833   | 43        | 4378  |
| 2000-01 | 162     | 333   | 3                    | 333   | 584            | 649   | 44        | 3847  |
| 2001-02 | 164     | 383   | 2                    | 500   | 672            | 778   | 42        | 3893  |
| 2002-03 | 143     | 353   | 2                    | 395   | 514            | 566   | 40        | 3991  |
| 2003-04 | 143     | 434   | 2                    | 535   | 682            | 943   | 44        | 4335  |
| 2004-05 | 133     | 394   | 2                    | 542   | 817            | 890   | 53        | 4093  |

Source –

Agricultural statistics published by Directorate of Agriculture, Madhya Pradesh

## APPENDIX 2

**Significant values  $t_v(\alpha)$  of t distribution two tailed test**

$$P [|t| > t_v(\alpha)] = \alpha$$

| d.f      | Probability level of significance |      |       |       |       |        |
|----------|-----------------------------------|------|-------|-------|-------|--------|
| v        | 0.50                              | 0.10 | 0.05  | 0.02  | 0.01  | 0.001  |
| 1        | 1.00                              | 6.31 | 12.71 | 31.82 | 63.66 | 636.62 |
| 2        | 0.82                              | 2.92 | 4.30  | 6.97  | 6.93  | 31.60  |
| 3        | 0.77                              | 2.35 | 3.18  | 4.54  | 5.84  | 12.94  |
| 4        | 0.74                              | 2.13 | 2.78  | 3.75  | 4.60  | 8.61   |
| 5        | 0.73                              | 2.02 | 2.57  | 3.37  | 4.03  | 6.86   |
| 6        | 0.72                              | 1.94 | 2.45  | 3.14  | 3.71  | 5.96   |
| 7        | 0.71                              | 1.90 | 2.37  | 3.00  | 3.50  | 5.41   |
| 8        | 0.71                              | 1.86 | 2.31  | 2.90  | 3.36  | 5.04   |
| 9        | 0.70                              | 1.83 | 2.26  | 2.82  | 3.25  | 4.78   |
| 10       | 0.70                              | 1.81 | 2.23  | 2.76  | 3.17  | 4.59   |
| 11       | 0.70                              | 1.80 | 2.20  | 2.72  | 3.11  | 4.44   |
| 12       | 0.70                              | 1.78 | 2.18  | 2.68  | 3.06  | 4.32   |
| 13       | 0.69                              | 1.77 | 2.16  | 2.65  | 3.01  | 4.22   |
| 14       | 0.69                              | 1.76 | 2.15  | 2.62  | 2.98  | 4.14   |
| 15       | 0.69                              | 1.75 | 2.13  | 2.60  | 2.95  | 4.07   |
| 16       | 0.69                              | 1.75 | 2.12  | 2.58  | 2.92  | 4.02   |
| 17       | 0.69                              | 1.74 | 2.11  | 2.57  | 2.90  | 3.97   |
| 18       | 0.69                              | 1.73 | 2.10  | 2.55  | 2.88  | 3.92   |
| 19       | 0.69                              | 1.73 | 2.09  | 2.54  | 2.86  | 3.88   |
| 20       | 0.69                              | 1.73 | 2.09  | 2.53  | 2.85  | 3.85   |
| 21       | 0.69                              | 1.72 | 2.08  | 2.52  | 2.83  | 3.83   |
| 22       | 0.69                              | 1.72 | 2.07  | 2.51  | 2.82  | 3.79   |
| 23       | 0.69                              | 1.71 | 2.07  | 2.50  | 2.81  | 3.77   |
| 24       | 0.69                              | 1.71 | 2.06  | 2.49  | 2.80  | 3.75   |
| 25       | 0.68                              | 1.71 | 2.06  | 2.49  | 2.79  | 3.73   |
| 26       | 0.68                              | 1.71 | 2.06  | 2.48  | 2.78  | 3.71   |
| 27       | 0.68                              | 1.70 | 2.05  | 2.47  | 2.77  | 3.69   |
| 28       | 0.68                              | 1.70 | 2.05  | 2.47  | 2.76  | 3.67   |
| 29       | 0.68                              | 1.70 | 2.05  | 2.46  | 2.76  | 3.66   |
| 30       | 0.68                              | 1.70 | 2.04  | 2.46  | 2.75  | 3.65   |
| $\infty$ | 0.67                              | 1.65 | 1.96  | 2.33  | 2.58  | 3.29   |

Source- Fundamentals of Mathematical Statistics by S.C. Gupta and V.K.

Kapoor, 11<sup>th</sup> edition June 2002, New Delhi.

**APPENDIX- 3**  
**TABLE OF RANDOM NUMBERS**

|    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|----|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1 | 2 | 5 | 4 | 2 | 8 | 5 | 8 | 7 | 3  | 5  | 8  | 4  | 0  | 2  | 4  | 3  | 6  | 8  | 4  | 8  | 4  | 8  | 5  | 2  | 6  | 1  | 7  | 5  | 4  | 8  | 8  |
| 2  | 5 | 4 | 4 | 3 | 4 | 9 | 1 | 1 | 0 | 9  | 2  | 2  | 7  | 1  | 3  | 4  | 4  | 7  | 9  | 8  | 1  | 3  | 1  | 1  | 8  | 7  | 0  | 1  | 2  | 2  | 1  | 0  |
| 3  | 3 | 2 | 6 | 2 | 2 | 3 | 2 | 2 | 4 | 1  | 1  | 2  | 9  | 8  | 7  | 7  | 4  | 7  | 7  | 6  | 4  | 5  | 1  | 2  | 1  | 7  | 4  | 6  | 2  | 5  | 9  | 3  |
| 4  | 7 | 8 | 0 | 9 | 0 | 2 | 9 | 7 | 8 | 9  | 5  | 6  | 2  | 1  | 5  | 8  | 7  | 7  | 8  | 0  | 0  | 7  | 5  | 3  | 1  | 2  | 3  | 2  | 7  | 1  | 8  | 1  |
| 5  | 6 | 8 | 6 | 2 | 4 | 1 | 9 | 4 | 3 | 5  | 9  | 6  | 5  | 0  | 7  | 2  | 4  | 4  | 7  | 3  | 3  | 0  | 9  | 9  | 0  | 7  | 2  | 9  | 4  | 9  | 5  | 0  |
| 6  | 9 | 1 | 7 | 9 | 3 | 8 | 1 | 4 | 9 | 1  | 5  | 3  | 2  | 1  | 2  | 7  | 6  | 7  | 4  | 5  | 9  | 6  | 4  | 6  | 8  | 1  | 0  | 5  | 3  | 1  | 3  | 3  |
| 7  | 5 | 3 | 1 | 7 | 0 | 9 | 8 | 6 | 0 | 6  | 3  | 3  | 6  | 4  | 8  | 0  | 4  | 8  | 3  | 4  | 8  | 7  | 1  | 0  | 8  | 8  | 2  | 9  | 8  | 5  | 7  | 2  |
| 8  | 0 | 1 | 2 | 6 | 4 | 7 | 7 | 7 | 8 | 0  | 3  | 4  | 9  | 2  | 1  | 7  | 2  | 1  | 2  | 8  | 2  | 2  | 3  | 2  | 5  | 0  | 3  | 9  | 8  | 6  | 3  | 7  |
| 9  | 2 | 3 | 7 | 2 | 7 | 7 | 7 | 4 | 9 | 4  | 4  | 6  | 7  | 1  | 7  | 8  | 8  | 4  | 0  | 3  | 3  | 9  | 7  | 1  | 0  | 8  | 9  | 9  | 5  | 2  | 7  | 4  |
| 10 | 0 | 3 | 5 | 7 | 5 | 2 | 7 | 6 | 3 | 9  | 9  | 9  | 0  | 2  | 6  | 1  | 9  | 2  | 5  | 5  | 5  | 7  | 8  | 0  | 5  | 7  | 2  | 8  | 0  | 0  | 3  | 2  |
| 11 | 7 | 8 | 5 | 5 | 9 | 7 | 0 | 7 | 5 | 2  | 5  | 9  | 4  | 2  | 6  | 3  | 9  | 8  | 7  | 8  | 4  | 9  | 1  | 8  | 0  | 9  | 8  | 7  | 9  | 1  | 1  | 8  |
| 12 | 2 | 5 | 1 | 0 | 4 | 2 | 5 | 4 | 1 | 5  | 4  | 3  | 0  | 2  | 2  | 4  | 0  | 1  | 1  | 2  | 6  | 5  | 2  | 3  | 8  | 6  | 6  | 7  | 4  | 7  | 0  | 7  |
| 13 | 6 | 6 | 3 | 9 | 1 | 9 | 1 | 3 | 3 | 1  | 2  | 0  | 9  | 1  | 4  | 9  | 6  | 1  | 4  | 5  | 5  | 8  | 9  | 5  | 0  | 7  | 2  | 6  | 3  | 8  | 8  | 3  |
| 14 | 6 | 7 | 6 | 9 | 1 | 4 | 3 | 5 | 9 | 1  | 0  | 7  | 4  | 7  | 6  | 2  | 9  | 9  | 0  | 2  | 3  | 7  | 6  | 4  | 7  | 3  | 8  | 8  | 2  | 7  | 2  | 9  |
| 15 | 4 | 5 | 2 | 7 | 8 | 0 | 0 | 0 | 8 | 6  | 4  | 8  | 3  | 3  | 6  | 6  | 7  | 9  | 4  | 5  | 4  | 8  | 4  | 7  | 4  | 3  | 1  | 7  | 9  | 6  | 3  | 6  |
| 16 | 5 | 6 | 9 | 9 | 9 | 8 | 8 | 3 | 2 | 4  | 5  | 6  | 0  | 8  | 9  | 3  | 4  | 1  | 3  | 2  | 6  | 6  | 6  | 8  | 0  | 7  | 9  | 9  | 6  | 1  | 3  | 7  |
| 17 | 4 | 1 | 6 | 0 | 1 | 4 | 4 | 5 | 2 | 8  | 8  | 7  | 0  | 7  | 2  | 4  | 1  | 2  | 9  | 4  | 8  | 9  | 8  | 8  | 1  | 5  | 2  | 7  | 1  | 4  | 6  | 7  |
| 18 | 4 | 5 | 0 | 6 | 2 | 4 | 7 | 4 | 3 | 5  | 9  | 0  | 5  | 3  | 0  | 8  | 7  | 6  | 4  | 0  | 1  | 1  | 2  | 8  | 1  | 0  | 2  | 3  | 2  | 4  | 1  | 8  |
| 19 | 4 | 6 | 4 | 5 | 0 | 6 | 1 | 3 | 9 | 8  | 4  | 6  | 4  | 4  | 5  | 8  | 5  | 6  | 6  | 6  | 7  | 6  | 7  | 1  | 1  | 1  | 8  | 4  | 2  | 3  | 2  | 8  |
| 20 | 6 | 6 | 8 | 6 | 3 | 5 | 4 | 4 | 9 | 8  | 2  | 8  | 9  | 1  | 8  | 7  | 0  | 5  | 0  | 6  | 6  | 4  | 7  | 3  | 5  | 3  | 5  | 6  | 8  | 9  | 4  | 0  |
| 21 | 6 | 5 | 0 | 3 | 0 | 3 | 2 | 9 | 7 | 8  | 9  | 9  | 8  | 2  | 1  | 1  | 0  | 8  | 5  | 2  | 8  | 0  | 6  | 6  | 5  | 7  | 0  | 6  | 1  | 9  | 4  | 0  |
| 22 | 1 | 6 | 5 | 8 | 4 | 2 | 8 | 8 | 1 | 8  | 5  | 6  | 5  | 3  | 1  | 9  | 3  | 5  | 1  | 2  | 8  | 9  | 8  | 1  | 7  | 4  | 6  | 8  | 3  | 8  | 3  | 6  |
| 23 | 1 | 3 | 1 | 9 | 1 | 2 | 0 | 4 | 3 | 3  | 4  | 4  | 8  | 8  | 8  | 6  | 3  | 9  | 4  | 6  | 6  | 7  | 7  | 7  | 7  | 1  | 7  | 0  | 0  | 3  | 2  | 3  |
| 24 | 5 | 0 | 3 | 0 | 4 | 0 | 2 | 7 | 2 | 0  | 7  | 7  | 9  | 8  | 1  | 2  | 8  | 6  | 4  | 5  | 3  | 2  | 9  | 0  | 7  | 1  | 9  | 1  | 6  | 1  | 5  | 2  |
| 25 | 7 | 8 | 6 | 6 | 2 | 0 | 2 | 9 | 5 | 1  | 5  | 6  | 2  | 0  | 0  | 3  | 2  | 9  | 4  | 0  | 0  | 2  | 3  | 7  | 7  | 6  | 7  | 0  | 2  | 8  | 5  | 2  |

**APPENDIX- 3**  
**CONTD.....**

|    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |   |
|----|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|
| 1  | 1 | 9 | 8 | 3 | 8 | 9 | 9 | 2 | 1 | 0  | 1  | 7  | 7  | 2  | 6  | 3  | 7  | 6  | 9  | 9  | 4  | 1  | 5  | 1  | 8  | 1  | 3  | 2  | 7  | 2  | 7  | 1  |   |
| 2  | 9 | 9 | 4 | 4 | 0 | 8 | 4 | 5 | 7 | 4  | 6  | 8  | 3  | 9  | 3  | 6  | 8  | 0  | 0  | 2  | 0  | 8  | 5  | 7  | 5  | 7  | 8  | 4  | 4  | 4  | 8  | 0  |   |
| 3  | 0 | 3 | 3 | 0 | 9 | 9 | 1 | 3 | 4 | 9  | 9  | 0  | 7  | 7  | 9  | 0  | 6  | 9  | 3  | 2  | 0  | 8  | 7  | 1  | 1  | 9  | 8  | 8  | 9  | 8  | 8  | 1  |   |
| 4  | 9 | 9 | 0 | 3 | 7 | 9 | 1 | 4 | 4 | 1  | 3  | 8  | 6  | 8  | 2  | 6  | 0  | 2  | 3  | 0  | 1  | 3  | 3  | 7  | 7  | 4  | 1  | 3  | 8  | 8  | 4  | 0  |   |
| 5  | 1 | 6 | 1 | 4 | 7 | 8 | 6 | 2 | 9 | 5  | 0  | 0  | 4  | 1  | 0  | 9  | 1  | 0  | 3  | 7  | 2  | 9  | 7  | 8  | 6  | 0  | 7  | 5  | 0  | 9  | 7  | 1  |   |
| 6  | 2 | 0 | 9 | 6 | 1 | 1 | 6 | 4 | 3 | 7  | 8  | 8  | 6  | 2  | 5  | 7  | 0  | 6  | 3  | 2  | 0  | 6  | 9  | 3  | 2  | 2  | 6  | 3  | 5  | 2  | 9  | 0  |   |
| 7  | 0 | 5 | 1 | 1 | 0 | 2 | 2 | 9 | 5 | 9  | 5  | 1  | 6  | 8  | 0  | 8  | 1  | 4  | 0  | 9  | 7  | 6  | 2  | 4  | 4  | 9  | 0  | 3  | 4  | 6  | 9  | 2  |   |
| 8  | 0 | 5 | 2 | 4 | 4 | 0 | 5 | 6 | 9 | 1  | 4  | 0  | 6  | 3  | 7  | 1  | 2  | 0  | 9  | 9  | 8  | 2  | 9  | 0  | 3  | 6  | 1  | 1  | 6  | 5  | 0  | 1  |   |
| 9  | 7 | 3 | 8 | 1 | 7 | 3 | 8 | 6 | 6 | 5  | 6  | 8  | 1  | 5  | 6  | 8  | 4  | 1  | 6  | 0  | 0  | 4  | 2  | 9  | 3  | 4  | 8  | 8  | 3  | 7  | 4  | 1  |   |
| 10 | 3 | 3 | 1 | 1 | 3 | 7 | 3 | 3 | 7 | 8  | 8  | 2  | 6  | 9  | 8  | 5  | 7  | 8  | 7  | 4  | 7  | 2  | 6  | 4  | 4  | 5  | 8  | 7  | 9  | 5  | 9  | 1  |   |
| 11 | 6 | 8 | 7 | 4 | 2 | 5 | 3 | 4 | 7 | 4  | 8  | 5  | 9  | 5  | 9  | 6  | 9  | 0  | 8  | 6  | 2  | 7  | 0  | 1  | 4  | 9  | 6  | 7  | 1  | 5  | 8  | 8  |   |
| 12 | 8 | 9 | 8 | 7 | 3 | 1 | 2 | 1 | 3 | 6  | 2  | 8  | 0  | 3  | 7  | 2  | 1  | 0  | 5  | 9  | 6  | 3  | 3  | 9  | 8  | 9  | 7  | 3  | 4  | 2  | 1  | 8  | 8 |
| 13 | 9 | 2 | 0 | 5 | 2 | 3 | 5 | 8 | 0 | 3  | 9  | 3  | 3  | 1  | 9  | 6  | 1  | 6  | 1  | 2  | 8  | 3  | 9  | 7  | 4  | 3  | 9  | 0  | 0  | 1  | 8  | 7  |   |
| 14 | 9 | 7 | 4 | 9 | 7 | 9 | 8 | 3 | 7 | 0  | 7  | 6  | 9  | 7  | 9  | 1  | 1  | 5  | 3  | 0  | 8  | 1  | 2  | 7  | 4  | 4  | 7  | 4  | 1  | 8  | 9  | 5  |   |
| 15 | 2 | 1 | 8 | 3 | 2 | 1 | 0 | 9 | 2 | 8  | 7  | 4  | 5  | 7  | 3  | 3  | 1  | 5  | 6  | 7  | 7  | 7  | 6  | 4  | 4  | 9  | 3  | 9  | 9  | 9  | 1  | 9  | 9 |
| 16 | 6 | 9 | 2 | 6 | 3 | 0 | 8 | 5 | 2 | 0  | 7  | 9  | 3  | 3  | 3  | 0  | 4  | 4  | 3  | 2  | 9  | 5  | 2  | 4  | 0  | 3  | 2  | 7  | 9  | 6  | 4  | 0  |   |
| 17 | 3 | 3 | 7 | 3 | 3 | 5 | 6 | 7 | 0 | 3  | 7  | 1  | 5  | 9  | 3  | 2  | 3  | 9  | 2  | 3  | 7  | 2  | 5  | 0  | 8  | 5  | 7  | 8  | 5  | 8  | 6  | 9  | 9 |
| 18 | 9 | 7 | 7 | 1 | 5 | 5 | 4 | 2 | 4 | 7  | 1  | 5  | 5  | 5  | 2  | 7  | 3  | 7  | 6  | 3  | 3  | 1  | 6  | 7  | 3  | 6  | 7  | 9  | 4  | 3  | 9  | 9  | 9 |
| 19 | 9 | 3 | 5 | 3 | 5 | 5 | 7 | 6 | 5 | 4  | 7  | 4  | 0  | 1  | 9  | 0  | 7  | 2  | 7  | 4  | 6  | 9  | 9  | 3  | 3  | 9  | 2  | 0  | 7  | 2  | 7  | 2  | 2 |
| 20 | 5 | 7 | 6 | 1 | 6 | 3 | 0 | 1 | 3 | 5  | 5  | 8  | 6  | 2  | 0  | 5  | 3  | 0  | 1  | 2  | 6  | 1  | 9  | 5  | 8  | 4  | 6  | 1  | 2  | 0  | 4  | 6  | 1 |
| 21 | 6 | 8 | 5 | 0 | 8 | 1 | 2 | 2 | 4 | 4  | 5  | 5  | 2  | 9  | 4  | 0  | 9  | 9  | 4  | 5  | 9  | 6  | 8  | 8  | 3  | 5  | 8  | 8  | 3  | 1  | 1  | 1  | 1 |
| 22 | 6 | 6 | 1 | 6 | 6 | 7 | 6 | 0 | 4 | 9  | 3  | 8  | 0  | 0  | 6  | 6  | 0  | 3  | 9  | 1  | 8  | 8  | 9  | 8  | 4  | 7  | 5  | 3  | 7  | 4  | 0  | 2  | 2 |
| 23 | 2 | 6 | 3 | 3 | 4 | 2 | 5 | 5 | 8 | 7  | 5  | 5  | 8  | 4  | 3  | 4  | 4  | 3  | 3  | 4  | 8  | 9  | 9  | 2  | 1  | 2  | 6  | 0  | 0  | 5  | 4  | 7  | 4 |
| 24 | 6 | 8 | 3 | 7 | 4 | 8 | 9 | 8 | 9 | 5  | 2  | 7  | 3  | 5  | 2  | 6  | 6  | 5  | 3  | 6  | 7  | 7  | 0  | 3  | 9  | 9  | 4  | 1  | 8  | 4  | 5  | 4  | 4 |
| 25 | 4 | 5 | 2 | 3 | 7 | 7 | 7 | 2 | 3 | 8  | 8  | 8  | 7  | 2  | 4  | 3  | 1  | 3  | 3  | 0  | 7  | 1  | 1  | 5  | 4  | 8  | 9  | 7  | 6  | 6  | 1  | 8  | 8 |

Source: Sampling theory of Surveys With Application by P V Sukhatme, B V Sukhatme, Shashikala Sukhatme and C. Asok, Third revised edition, 1984, Peg No 19-20, New Delhi

## VITA

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