AN IMPROVED ESTIMATION OF POPULATION MEAN IN AGRICULTURAL SURVEY BY USING SAMPLE SIZE INFORMATION

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Abstract

The sample size in the current work has been used as information to more accurately estimate the population mean of the primary variable under investigation. In a variety of socioeconomic and agricultural surveys, sample size is a crucial component for estimating population parameters. The population mean has been estimated using a generalised ratio type estimator. The bias and mean squared error of the proposed estimator's large sample properties have been obtained to within one order of precision. The ideal mean squared error-minimizing value of the characterising scalar has been found, and the ideal mean squared error-minimizing value of the proposed estimator has also been found. The suggested estimator has been compared to mean. The proposed estimator has been compared to mean per unit estimate and other popular population mean estimators. A numerical analysis is also done to compare the efficiencies of proposed and existing population mean estimators.

Key words: Sample Mean, Population Mean, Bias, Mean squared error, Efficiency.

1. INTRODUCTION

For the many agriculture-related programmers to make effective policy decisions, credible estimates are essential. Reliable crop projections are essential for the successful execution of agricultural initiatives. These estimates were derived from a number of surveys connected to agriculture, including the CCS (Crop Cutting Surveys). Generally, whenever we deal with on variable under study the most appropriate measures of central tendency is Arithmetic Mean. Whenever the population is very large, it is natural and economic to estimate the population parameters through appropriate sampling technique. It is inevitable to estimate any population parameters through its corresponding statistics. For example, to estimate the population mean of the variable under study, sample mean is the most appropriate estimator for the estimation of population mean. Although the sample mean is an unbiased estimator of population mean but has reasonably large amount of variation. Generally, it is desirable to have an estimator which may even be biased but it should have minimum Mean Squared Error (MSE). Generally, it is an obvious fact that to enhance the efficiency of the estimators of population mean use of auxiliary variable is made**.** Auxiliary variable are the variables about which we have full information and they are highly positively or negatively correlated with main variable under study. For example, for improved estimation of population average consumption of a family, family size (demographic variable) can be used as an auxiliary variable. Well-known methods for estimating the population parameters with the use of auxiliary variables are the ratio method of estimation and regression method of estimation. Population mean is one of the very important measures of central tendency used in almost all fields of society including field of agriculture. Thus, the estimation of population mean is of great significance in agriculture related areas. In this present manuscript, a modified ratio type estimator of population mean of the study variable using information on size of the sample has been proposed and its large sample properties have been studied up to the first order of approximation.

2. NOTATIONS AND TERMINOLOGY

Let the finite population U is made up of N different and recognizable units $U_1, U_2, ..., U_N$ and the 'Simple Random Sampling Without Replacement' (SRSWOR) method is used to collect a sample of size n units from this population, assuming that Y and X has a strong correlation between them. Let (Y_i, X_i) be the observation on the ith unit of the population, $i = 1, 2, ..., N$. The manuscript contains the notations shown below.

N - Population Size

n - Sample Size

Y - Study variable

X - Auxiliary variable

$\bar{Y}$, $\bar{X}$ - Population means

$\bar{y}$, $\bar{x}$ - Sample means

S_y, S_x - Population Standard Deviations

S_{yx} - Population Covariance between Y and X

C_y, C_x - Coefficients of Variations

M_x - Median of X

ρ - Correlation coefficient between Y and X

β_1 - Coefficient of Skewness of X

β_2 - Coefficient of Kurtosis of X

where,

$$\bar{Y} = \frac{1}{N}\sum_{i=1}^{N} Y_i \quad , \quad \bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i \quad , \quad C_y = \frac{S_y}{\bar{Y}} \quad , \quad S_y^2 = \frac{1}{N-1}\sum_{i-1}^{N}(Y_i - \bar{Y})^2 \quad , \quad C_x = \frac{S_x}{\bar{X}} \quad ,$$

$$S_x^2 = \frac{1}{N-1}\sum_{i-1}^{N}(X_i - \bar{X})^2 \quad , \quad \rho_{yx} = \frac{Cov(x,y)}{S_x S_y} \quad , \quad C_{yx} = \rho_{yx} C_y C_x \quad , \quad \lambda = \frac{1}{n} - \frac{1}{N} \quad ,$$

$$Cov(x,y) = \frac{1}{N-1}\sum_{i-1}^{N}(Y_i - \bar{Y})(X_i - \bar{X}) \, , \; \beta_1 = \frac{N\sum_{i-1}^{N}(X_i - \bar{X})^3}{(N-1)(N-2)S_x^3} \, ,$$

$$\beta_2 = \frac{N(N+1)\sum_{i-1}^{N}(X_i - \bar{X})^4}{(N-1)(N-2)(N-3)S_x^4} - \frac{3(N-1)^2}{(N-2)(N-3)}$$

Review of Existing Estimators-

In this section, for an approximation of first order many $\bar{Y}$ estimators along with their MSEs have been shown by us

The associated statistic $\bar{y}$ is the most appropriate estimator for $\bar{Y}$, given by,

$$t_0 = \bar{y} = \frac{1}{n}\sum_{i=1}^{n} Y_i$$

It is unbiased for $\bar{Y}$, and given an approximation of order one, its sampling variance is,

$$V(t_0) = \lambda \bar{Y}^2 C_y^2 \qquad (1)$$

Cochran (1940) suggested the usual ratio estimator of $\bar{Y}$, utilizing the known $\bar{X}$ as,

$$t_r = \bar{y}\left(\frac{\bar{X}}{\bar{x}}\right)$$

Where, $\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$ and $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} X_i$

It is a biased estimator and the MSE for the first degree approximation is,

$$MSE(t_r) = \lambda \bar{Y}^2 [C_y^2 + C_x^2 - 2C_{yx}] \tag{2}$$

A different ratio type estimator of population mean was suggested by Sisodia and Dwivedi (1981). In this estimator utilization of the known C_x was made, the expression for estimator of $\bar{Y}$ is given by-

$$t_1 = \bar{y}\left(\frac{\bar{X} + C_x}{\bar{x} + C_x}\right)$$

The expression for MSE of the above estimator up to first degree approximation is given by

$$MSE(t_1) = \lambda \bar{Y}^2 [C_y^2 + \theta_1^2 C_x^2 - 2\theta_1 C_{yx}] \tag{3}$$

Where, $\theta_1 = \frac{\bar{X}}{\bar{X} + C_x}$

A new improved estimator of study variable $\bar{Y}$ was suggested by Upadhyaya and Singh (1999) by using the known β_2. The expression for the estimator is given by,

$$t_2 = \bar{y}\left(\frac{\bar{X}C_x + \beta_2}{\bar{x}C_x + \beta_2}\right)$$

The MSE of t_2 for an approximation of order one is,

$$MSE(t_2) = \lambda \bar{Y}^2 [C_y^2 + \theta_2^2 C_x^2 - 2\theta_2 C_{yx}] \tag{4}$$

Where, $\theta_2 = \frac{\bar{X}C_x}{\bar{X}C_x + \beta_2}$

Singh and Tailor (2003) worked on improved estimation of $\bar{Y}$ using known ρ between Y and X they have introduced an estimator of $\bar{Y}$ as,

$$t_3 = \bar{y}\left(\frac{\bar{X} + \rho}{\bar{x} + \rho}\right)$$

The MSE of t_3 for the first order approximation is,

$$MSE(t_3) = \lambda \bar{Y}^2 [C_y^2 + \theta_3^2 C_x^2 - 2\theta_3 C_{yx}] \tag{5}$$

Where, $\theta_3 = \dfrac{\bar{X}}{\bar{X} + \rho}$

Singh *et al.* (2004) utilized the known information on β_2 and proposed an enhanced estimator of $\bar{Y}$ as,

$$t_4 = \bar{y}\left(\frac{\bar{X} + \beta_2}{\bar{x} + \beta_2}\right)$$

The MSE of t_4 for an approximation of order one is,

$$MSE(t_4) = \lambda \bar{Y}^2 [C_y^2 + \theta_4^2 C_x^2 - 2\theta_4 C_{yx}] \tag{6}$$

Where, $\theta_4 = \dfrac{\bar{X}}{\bar{X} + \beta_2}$

Yan and Tian (2010) suggested an estimator of $\bar{Y}$ by using the known β_1 as,

$$t_5 = \bar{y}\left(\frac{\bar{X} + \beta_1}{\bar{x} + \beta_1}\right)$$

The MSE of t_5 for an approximation of order one is,

$$MSE(t_5) = \lambda \bar{Y}^2 [C_y^2 + \theta_5^2 C_x^2 - 2\theta_5 C_{yx}] \tag{7}$$

Where, $\theta_5 = \dfrac{\bar{X}}{\bar{X} + \beta_1}$

Utilization of the known median M_x was carried out by Subramani and Kumarpandiyan (2013) in the following estimator of $\bar{Y}$ as,

$$t_6 = \bar{y}\left(\frac{\bar{X} + M_x}{\bar{x} + M_x}\right)$$

The MSE of t_6 for an approximation of up to degree one is,

$$MSE(t_6) = \lambda \bar{Y}^2 [C_y^2 + \theta_6^2 C_x^2 - 2\theta_6 C_{yx}] \tag{8}$$

Where, $\theta_6 = \dfrac{\bar{X}}{\bar{X} + M_x}$

Making use of known information of size of sample, n, Jerajuddin and Kishun (2016) suggested the following estimator of $\bar{Y}$ with following expression,

$$t_7 = \bar{y}\left(\frac{\bar{X}+c}{\bar{x}+c}\right)$$

The MSE of t_7 for an approximation up to degree one is,

$$MSE(t_7) = \lambda \bar{Y}^2 [C_y^2 + \theta_7^2 C_x^2 - 2\theta_7 C_{yx}] \tag{9}$$

Where, $\theta_7 = \dfrac{\bar{X}}{\bar{X}+c}$

Jaroengeratikun and Lawson (2019) suggested a new estimator of population mean expression for tis estimator is given by

$$t_8 = \bar{y}\left(\frac{a\bar{X}+c}{a\bar{x}+c}\right)$$

The expression for MSE of t_8 for an approximation up to degree one is given by,

$$MSE(t_8) = \lambda \bar{Y}^2 [C_y^2 + \theta_8^2 C_x^2 - 2\theta_8 C_{yx}] \tag{10}$$

Where, $\theta_8 = \dfrac{a\bar{X}}{a\bar{X}+c}$

3. PROPOSED ESTIMATOR

In the light of the estimator of population mean suggested by Jaroengeratikun and Lawson (2019) , we propose the following ratio type estimator using information on the size of the sample, n, and the known C_x .

Thus proposed estimator will be,

$$\mathrm{T_p} = \left[\frac{C_x\bar{X}+n}{C_x\bar{X}+n}\right]^{\alpha} \tag{11}$$

To study the large sample properties of the estimator, we define .

$\bar{y} = \bar{Y}(1+e_0)$ and $\bar{x} = \bar{X}(1+e_1)$ with $E(e_0) = E(e_1) = 0$ and $E(e_0^2) = \lambda C_y^2$ $E(e_1^2) = \lambda C_x^2$, $E(e_0 e_1) = \lambda C_{yx}$

Expressing T_p in terms of $e_i's$ ($i = 0,1$), we have

$$T_p = \bar{Y}(1+e_0)\left[\frac{C_x\bar{X}+n}{C_x\bar{X}(1+e_1)+n}\right]^{\alpha}$$

$$=\bar{Y}(1+e_0)(1+\theta e_1)^{-\alpha}$$

Where $\theta = \frac{C_x\bar{X}}{C_x\bar{X}+n}$

After Taylor series expansion and ignorance of terms of higher order expression for T_p may be written as

$$T_p = \bar{Y}(1+e_0)[1-\theta\alpha e_1 + (\alpha^2+\alpha)\theta^2 e_1^2]$$

$$T_p - \bar{Y} = \bar{Y}[e_0 - \theta\alpha e_1 - \alpha\theta e_0 e_1 + (\alpha^2+\alpha)\theta^2 e_1^2]$$

After taking expectation on both sides of above equation we are going to get expression for Bias of T_p

$$\text{Bias}\,(T_p) = \bar{Y}\left[(\alpha^2+\alpha)\theta^2\lambda C_x^2 - \theta\alpha\lambda C_{yx}\right] \qquad (12)$$

In the same way we have derived expression for MSE of proposed estimator as

$$\text{MSE}(T_p)=\bar{Y}^2\lambda[C_y^2 + \alpha^2\theta^2 C_x^2 - 2\alpha\theta C_{yx}] \qquad (13)$$

The optimum value of α which minimizes the MSE of T_p, obtained by using Maxima Minima Technique, is given by

$$\alpha = \frac{C_{yx}}{\theta C_x^2}$$

Using this expression, we can find expression for the minimum MSE as

$$\text{MSE}_{\text{min}}\,(T_p) = \lambda\bar{Y}^2 C_y^2(1-\rho^2) \qquad (14)$$

4. THEORETICAL EFFICIENCY COMPARISON

In this section, theoretical comparison between the efficiency of the recommended estimator and the previously well known existing $\bar{Y}$ estimators has been done by us. We have also identified the conditions in which the suggested estimator outperforms the completion estimate. When the following conditions are met, the suggested estimator T_p is more effective than the estimator t_0.

$V(t_0) - \text{MSEmin} > 0$, or

$$\lambda\bar{Y}^2 C_y^2\rho^2 > 0 \qquad (15)$$

The introduced estimator T_p performs better than the estimator t_r suggested by Cochran

(1940) for the following condition if,

$$MSE(t_r) - MSE_{min}(T_p) > 0$$

Or

$$\lambda\bar{Y}^2C_x^2 + \lambda\bar{Y}^2C_y^2\rho^2 - 2\lambda\bar{Y}^2C_{yx} > 0 \quad (16)$$

The suggested estimator T_p is more efficient than that of the estimator t_1 of Sisodia and Dwivedi (1981) for the following condition if,

$$MSE(t_1) - MSE_{min}(T_p) > 0$$

$$\theta_1^2C_x^2 + C_y^2\rho^2 - 2\theta_1C_{yx} > 0 \quad (17)$$

The suggested estimator T_p is more efficient than that of the estimator t_2 derived by Upadhyaya and Singh (1999) under the condition if,

$$MSE(t_2) - MSE_{min}(T_p) > 0$$

Or $$\theta_2^2C_x^2 + C_y^2\rho^2 - 2\theta_2C_{yx} > 0 \quad (18)$$

The suggested estimator T_p is more efficient than that of the estimator t_3 of Singh and Tailor (2003) if the following criteria are met,

$$MSE(t_3) - MSE_{min}(T_p) > 0$$

Or $$\theta_3^2C_x^2 + C_y^2\rho^2 - 2\theta_3C_{yx} > 0 \quad (19)$$

The suggested estimator T_p is more efficient than that of the estimator t_4 of Singh *et al.* (2004) for the criteria if,

$$MSE(t_4) - MSE_{min}(T_p) > 0$$

Or $$\theta_4^2C_x^2 + C_y^2\rho^2 - 2\theta_4C_{yx} > 0 \quad (20)$$

When compared to Yan and Tian (2010) estimator t_5, the recommended estimator T_p is more effective for the condition if,

$MSE(t_5) - MSE_{min}(T_p) > 0$

Or $\theta_5^2 C_x^2 + C_y^2 \rho^2 - 2\theta_5 C_{yx} > 0$ (21)

The introduced estimator Tp has lesser MSE than t_6 of Subramani and Kumarpandiyan (2013) under the condition if,

$$MSE(t_6) - MSE_{min}(T_p) > 0$$

Or, $\theta_6^2 C_x^2 + C_y^2 \rho^2 - 2\theta_6 C_{yx} > 0$

The suggested estimator T_p is more efficient than that of the estimator t_7 of Jerajuddin and Kishun (2016) under the following condition if,

$MSE(t_7) - MSE_{min}(T_p) > 0$,

or $\theta_7^2 C_x^2 + C_y^2 \rho^2 - 2\theta_7 C_{yx} > 0$

The suggested estimator T_p is more efficient than that of the estimator t_8 of Jaroengeratikun and Lawson (2019) if the following condition has been satisfied

$MSE(t_8) - MSE_{min}(T_p) > 0$,

$\theta_8^2 C_x^2 + C_y^2 \rho^2 - 2\theta_8 C_{yx} > 0$

5. NUMERICAL STUDY

We have taken into consideration a real natural population from Murthy in order to assess the performances of the suggested and competing estimates of $\overline{Y}$ and to confirm the efficiency criteria of the provided estimator over the indicated existing estimators (1967). Following are the main and auxiliary variables of the considered population under consideration:

Y : Output for 80 factories in a region

X : Number of workers

The parameters of the population under consideration are presented in Table-1.

Table-1: Parameters of the considered population

Sr. No.	Parameter	Value
1	N	80
2	n	20
3	$\bar{Y}$	51.8264
4	$\bar{X}$	11.2646
5	ρ	0.9413
6	C_y	0.3542
7	C_x	0.7505
8	β_1	1.0500
9	β_2	0.0634
10	M_X	7.5750

In table 2 we have shown the MSE of suggested estimator $\boldsymbol{T_p}$, the mentioned estimators stated above, and the percentage relative efficiency (PRE) of different estimators with respect to estimator t_0.

Table-2: MSE of various estimators and their respective PRE with respect to estimator t_0

Sr. No.	Estimator	MSE	PRE
1	$\boldsymbol{t_0}$	12.6366	100.0000
2	$\boldsymbol{t_r}$	18.9793	66.5809
3	$\boldsymbol{t_1}$	15.2581	82.8189
4	$\boldsymbol{t_2}$	19.4592	64.9388

5	t_3	14.4502	87.4489
6	t_4	19.3383	65.3449
7	t_5	14.0112	90.1888
8	t_6	2.7825	454.1387
9	t_7	1.8389	687.1801
10	t_8	2.4158	523.0813
11	T_p	1.4399	877.6033

6. RESULTS AND DISCUSSION

In the present study we have proposed a ratio type estimator of variable under study, we have utilized known parameter C_x of auxiliary variable information of sample size n. Expressions Bias and Mean square error (MSE) of the introduced estimator are derived up to the approximation of first order. The theoretical comparison of the suggested estimator with the already-existing estimators previously discussed determines the proposed estimator's efficiency criteria relative to its competing estimators. For verification of these efficiency conditions a population from Murthy (1967) is used. From table 2 it is clear that the MSEs of competing estimators lies within th6e range of [1.838908, 18.97931] on the other hand MSE of proposed estimator is **1.4399** and PREs of competing estimators with6 respect to estimator t_0 fall in the interval [64.93883, 687.1801] while the PRE of introduced estimator is 877.6033. Thus, it is clear that Tp estimator of $\bar{Y}$ is better than other estimators in the terms of efficiency. Thus, proposed estimator is recommended to survey practitioners for its use in various agriculture surveys. Survey professionals are thus advised to apply the proposed estimator in a variety of agricultural surveys.

References

[1] Abid, M., Abbas, N. Sherwani, R.A.K. & Nazir, H.Z. (2016). Improved ratio estimators for the population mean using non-conventional measure of dispersion, *Pakistan Journal of Statistics and Operations Research*, 12 (2), 353-367.

[2] Al-Omari, A.I., Jemain, A.A. & Ibrahim, K. (2009). New Ratio Estimators of the Mean using Simple Random Sampling and Ranked set Sampling Methods, *Investigacion Operacional*, 30(2), 97- 108.

[3] Baghel, S. & Yadav, S.K. (2020). Restructured class of estimators for population mean using auxiliary variable under simple random sampling scheme, *JAMSI*, 16(1), 61-74.

[4] Bahl, S. & Tuteja, R.K. (1991). Ratio and Product Type Exponential Estimators, *Journal of Information and Optimization Sciences*, 12(1), 159-164.

[5] Cochran, W.G. (1940). The Estimation of the Yields of the Cereal Experiments by Sampling for the Ratio of Grain to Total Produce, *The Journal of Agric. Science*, 30, 262-275.

[6] Gupta, S. & Shabbir, J. (2008). On the improvement in estimating the population mean in simple random sampling, *Journal of Applied Statistics*, 35(5), 559-566.

[7] Jaroengeratikun, U. and Lawson,(2019) N. A combined family of ratio estimators for population mean using an auxiliary variable in simple random sampling, Journal of Mathematics and Fundamental Sciences. , Vol. 51(1): 1–12.

[8] Ijaz, M. & Ali, H. (2018). Some improved ratio estimators for estimating mean of finite population, *Research & Reviews: Journal of Statistics and Mathematical Sciences*, 4(2),18-23.

[9] Jeelani, M.I., Maqbool, S. & Mir, S.A. (2013). Modified Ratio Estimators of Population Mean using Linear Combination of Coefficient of Skewness and Quartile Deviation, *International Journal of Model Mathematical Sciences*, 6(3), 174-183.

[10] Jerajuddin, M. & Kishun, J. (2016). Modified Ratio Estimators for Population Mean Using Size of the Sample selected from the Population, *International Journal of Scientific Research in Science, Engineering and Technology*, 2(2), 10-16.

[11] Koyuncu, N. & Kadilar, C. (2009). Efficient estimators for the population mean, *Hacettepe Journal of Mathematics and Statistics*, 38(2), 217-225.

[12] Murthy, M.N. (1967). *Sampling Theory and Methods*, Statistical Publishing Society, Calcutta.

[13] Shabbir, J. & Gupta, S. (2011). On estimating finite population mean in simple and stratified sampling, *Communications in Statistics-Theory and Methods*, 40(2), 199-212.

[14] Sharma, P. & Singh, R. (2013). Improved estimators for simple random sampling and stratified random sampling under second order of approximation, *Statistics in Transition-New Series*, 14(3), 379-390.

[15] Singh, H.P & Solanki, R.S. (2012). Improved estimation of population mean in simple random sampling using information on auxiliary attribute, *Applied Mathematics and Computation*, 218(15), 7798-7812.

[16] Singh, H.P. & Tailor, R. (2003). Use of known Correlation Coefficient in Estimating the Finite Population Mean, *Statistics in Transition*, 6(4), 550-560.

[17] Singh, H.P., Tailor, R. & Kakran, M.S. (2004). An improved Estimator of population mean using power transformation, *Journal of Indian Society of Agricultural Statistics*, 58(2), 223-230.

[18] Sisodia, B.V.S. and Dwivedi, V.K (1981). A modified ratio estimator using coefficient of variation of auxiliary variable, *Journal of the Indian Society of Agricultural Statistics*, 33, 13-18.

[19] Soni S.S. and Pandey H. (2022) Enhanced estimation of Population Mean utilizing5 known sample size information, Bulletin of Math6ematics and statistics Reasearch, 10(3), 4-17.

[20] Subramani, J. & Kumarapandiyan, G. (2012). Estimation of Population Mean using known Median and Coefficient of Skewness, *American Journal of Mathematics and Statistics*, 2(5), 101-107.

[21] Suleiman, S.A. and Adewara, A.A. (2021). Improved Modified Ratio Estimation of Population Mean Using Information on Size of the Sample, *Tanzania Journal of Science*, 47(5): 1753-1765.

[22] Upadhyaya, L.N. & Singh, H.P. (1999). Use of Transformed Auxiliary Variable in Estimating the Finite Population Mean, *Biometrical Journal*, 41, 627-636.

[23] Yadav, S.K. & Kadilar, C. (2013a). Improved class of ratio and product estimators, *Applied Mathematics and Computation*, 219, 10726-10731.

[24] Yadav, S.K. & Kadilar, C. (2013b). Efficient family of exponential estimator for population mean, *Hacettepe Journal of Mathematics and Statistics*, 42(6), 671-677.

[25] Yadav, S.K. & Mishra, S.S. (2015). Developing improved predictive estimator for finite population mean using auxiliary information, *Statistika*, 95(1), 76-85.

[26] Yadav, S.K. & Pandey, H. (2017). A new difference type median based estimator of the finite population mean, *International journal of Agricultural and Statistical Sciences*, 13(1), 289-295.

[27] Yadav, S.K., Gupta, S., Mishra, S.S. & Shukla, A.K. (2016). Modified ratio and product estimators for estimating population mean in two-phase sampling, *American Journal of Operational Research*, 6(3), 61-68.

[28] Yadav, S.K., Singh, L., Mishra, S.S., Mishra, P.P. & Kumar,S. (2017). A median based regression type estimator of the finite population mean, *International Journal of Agricultural and Statistical Sciences*, 13(1), 265-271.

[29] Yadav, S.K., Sharma, D.K., Mishra, S.S. & Shukla,A.K. (2018). Use of auxiliary variables in searching efficient estimator of population mean, *International Journal of Multivariate Data Analysis*, 1(3), 230-244.

[30] Yadav, S.K., Dixit, M.K., Dungana, H.N. & Mishra, S.S. (2019). Improved Estimators for Estimating Average Yield Using Auxiliary Variable, *International Journal of Mathematical Engineering and Management Sciences*, 4(5), 1228-1238.

[31] Yadav, S.K., Sharma, D.K. & Kadilar, C. (2021). New family of estimators for population mean using regression-cum-ratio exponential estimators, *International Journal of Mathematics in Operational Research*, 18(1), 85-114.

[32] Yadav, S.K., Sharma, D.K. & Brown, K. (2022). Estimating peppermint oil yields with auxiliary variable information, *International Journal of Operational Research*, 44(1), 122-139.

[33] Yan, Z. & Tian, B. (2010). Ratio Method to the Mean Estimation using Coefficient of Skewness of Auxiliary Variable, *ICICA 2010, Part II, CCIS*, 106, 103-110.

[34] Zaman, T. (2019). Improvement in estimating the population mean in simple random sampling using coefficient of skewness of auxiliary attribute, *Journal of Natural and Applied Sciences*, 23(1), 98-102.

[35] Zatezalo, T., Gupta, S., Yadav, S.K. and Shabbir, J. (2018). Assessing the Adequacy of First Order Approximations in Ratio Type Estimators, *Journal of Interdisciplinary Mathematics*, 21, 6, 1395-1411.