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# The Impact of Monsoon Rainfall Distribution on Major Kharif Crops Production in Haryana

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ABSTRACT

*Haryana's rice not only serves the food needs of the country but also plays an important role in trade. Rice is a high-water intensive crop. Due to less rainfall, rice production has to depend heavily on other sources which has a negative impact on the ground water level. In Haryana rice is sown during Kharif season. Kharif season crops are mainly grown during peak monsoon period during which monthly rainfall distribution has a great influence on these crops, especially rice which requires more water. In the present paper, correlation of monthly rainfall with yield of two main crops in Kharif has been studied. The study is based on secondary data. To know the impact of monthly rainfall distribution, ten years' time series data has been taken. The impact of monthly rainfall has been observed with the help of statistical tools like multivariate regression and growth rate. The study concludes that monthly rainfall distribution has more impact on millet crop as compared to rice. The study also shows that in the last ten years there has been more growth in the rice crop area as compared to millet.*

**Keywords:** Monsoon, Distribution of Rainfall, Kharif, Crop, Productivity.

## INTRODUCTION

Haryana is known worldwide for rice production. Haryana grown rice is exported to many countries. Almost 60 percent of total exported rice is produced in the state (Jaiprakash, 2019). Along with this Haryana makes a huge contribution to the central foodgrain pools (Indian Chamber of Food and Agriculture, 2019). Rice is sown in kharif season in Haryana. According to the study by Balwinder Singh et al. (2020) almost 65 percent was planted till the last week of June. Rice is a very deep-water intensive crop (Souryabrata M. et al., 2024), which requires very high level of water for its plant. As compare to other crops rice require more water after crop of sugar cane. But since rice is a gainful crop, farmers tried their best to produce rice even in dry and semi dry areas. Farmers depend on monsoon rain for rice production where sufficient irrigation facility is not available, or in other words we can say that rice sown and production is based on monsoon rainfall in Haryana.

In this extend Ashok Gulati et al. (2013) in their research concluded that 1 percent change in monsoon rainfall in a year caused close to 0.34 percent change in agricultural GDP of the year. Hence, the importance of rainfall in agricultural production especially in rice production cannot be ignored.

As discussed earlier that rice is a very high-water profound crop. While rice production in Haryana has created a name for itself in the world, on the other side the sustainability also paid its price. The ground water level downed in last few decades, according to a report the ground water level of Haryana was 4.68 meter in June 1974 which fall to 7.68 meter in June 2009 (Haryana Hydrological Cell, 2010). Moreover, it was also testified by scholars that the quality of the water deteriorated as well (R Prakash et al., 2023). To deal with this situation, the Haryana Government and Centre Government took several steps. The most important of which was *Mera Pani Meri Virasat*. Mera Pani Meri Virasat (https://agriharyana.gov.in) was

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announced in 2020. Top ten districts were highlighted for implementing this scheme, which had more area under sugar cane and rice (Ministry of Agriculture, Govt. of Haryana). To reduce the area under rice, the government announced an incentive of ₹7,000 per acre to those farmers who produced Jawar, cotton and vegetables instead of rice. Even after the scheme having good results for quite some time, both the area and production of rice crop have increased in the last four years, the area under rice was increase by 1661 (000 Ha.) in 2021–22 from 1559 (000 Ha.) in 2019–20 and production 5920 (mt. ton) in 2022–23 from 5198 (mt. ton) in 2019–20 (Different Volume of Haryana Statistical Abstract).

There was huge dependence on water for rice production in Haryana. This requirement depends either on the irrigation facility or on monsoon rain. Irrigation facilities have their limits; still total irrigated area increased in last decade from 83 percent to 91 percent from 2005 to 2019–20 (Ajay et al., 2024). Net irrigated area reached almost 94 percent according to Ministry of Agriculture Haryana. Other then irrigation facilities rain water is other important source of irrigation of paddy in Haryana.

Rice mainly produced in kharif season from June to October in India. The ideal temperature range of rice is 25–35 degree Celsius (Anil Nishad et al., 2018). Rice requires rainfall ranging from approximately 150–200 mm (Tamil Nadu Agriculture University, Coimbatore, Tamil Nadu).

## LITERATURE REVIEW

To understand the subject matter more thoroughly, past studies were reviewed, some of which are as follows. Arabind M. et al. (2024) in their research paper explained that the dependence of rice on monsoon rainfall. Paper explained the response of rice yield to monsoon rainfall in India by analyzing historical and rice production statistics and climate data from 1990 to 2017. Study concludes the lack and more rainfall effect on the rice production. Ushasi Bhattacharya (2022) in her research work highlighted the factors affecting rice cultivation in India. This paper also explained the importance of computer and different applications for famers and agriculture sector. The study concludes that insufficient soil moisture, fertility, draught, flood and uncertain monsoon were responsible factors for effecting rice production. Future study suggested some helping applications and software for farming. V.P. Singh and R.K. Maiti (2016), in their research work examined the seedling establishment process of Paddy. Study referred earlier research work conducted by different authors in this area. With the help of this literature, authors concluded that priming rice seeds before sowing them directly is very effective in increasing the yields. In case of high and low temperature, study suggested that both conditions affect rice production. Moreover, study also suggested some indicators to measure the impact of high temperature. Saumya Verma (2019) examined the impact of weather variability on rice production. The study is based on district level data from 1966–1999. Study concludes that higher rainfall increases mean yield of rice. Moreover study also shows a decreasing trend in early and late monsoon rainfall during observation years. Haruhisa Asada and Jun Matsumoto (2009) in their research work examine the impact of rainfall on Ganga–Brahmaputra basin with the help of statistical modelling. Authors explored time series data of rainfall and rice production. Study concludes that the effect of rainfall variation on rice production change over time. In the study area the effect of rainfall on rice production differ by region, so research should be carried out at a regional scale. Chairani, S. (2021) presented correlation between rainfall, temperature and climatic factors on rice production with the help of this paper. Data for ten years were arranged for the research. The findings of the study differed from previous research. The climatic condition of Besar were disturbed due to many climatic causes such as drought, high temperature, etc. Study concluded that larger period data is required for more clarity. Souryabrata M. et al. (2024) in their research paper explained about the role of rainfall on rice production. Authors presented a bird-eye view of global position of rice production on rainfall with the help of previous research work. Study used ICRISAT data base. Study concluded that rice yield in India was significantly impacted by primary, secondary, spillover effects of both weather and non-weather parameters. Study also observed that maximum and minimum temperature and evapotranspiration during monsoon and autumn negatively affect rice yield, on contrary rainfall has positive influence given the water intense nature of the

crop. Finally study suggested that government should formulate dynamic precautions and policies to bridge the gap. However different past studies had different opinion regarding the theory of monsoon rainfall and kharif crop productivity. Rahul et al. (2020) in their research paper concluded the crop wise impact of rainfall during kharif season. Rice, Millet, maize and cotton showed negative relationship with rainfall, on the other hand moong crops had positive relation in study periods. On the other hand (Abhilash Singh Chauhan et al., 2024) in their research paper highlighted that the decreasing rainfall leads to decrease the productivity of rice and increase the rainfall increase the productivity in millet production during study years in Haryana. however coefficient of maximum and minimum temperature were not significant on rice production during the study years. Gain Report (2009) concludes that poor rainfall of monsoon leads to decrease the production of rice in Northen stated of India.

It may be concluded with above discussion that the efficacy of rainfall during monsoon played an important role in kharif crop production. The impact of rainfall on rice production must be impacted on the alternative crop of rice in kharif season. To under the discussed concept in simple manner, the distribution of monsoon rainfall and its impact on major kharif crops is the key aspects of this research paper.

The Indian south–west (summer) monsoon typically lasts from June–Sept each year, where western and central area received almost 90 percent of their total rainfall (Climate Prediction Centre, Govt of India). Haryana received 430 normal rainfall during summer monsoon (IMD, India 2024). Rainfall distribution for months of monsoons were different. Normally it was high in September followed by August, July and June respectively. The distribution of rainfall in different months also played a significant role in production of different crops in kharif season. In the present research paper an attempt has been made to know what should be the optimum distribution of monsoon rainfall for maximum yield (of study years) rice and millet and how much impact the rainfall has on the production of rice and millet (http://www.agritech.tnau.ac.in). Rice and millet are the main crops of Kharif season of the specific research area. Obviously, if a farmer leaves rice and goes for some other crop, it is compared with rice. In case of Haryana and specially for study area Sonipat, where the production trends of other main crops of Kharif season and its relation with monsoon rain also needs to be seen. Millet is the second main crop of Kharif season in Sonpiat of study years. In the last few years, coarse grains were being given a lot of importance. Similarly, Haryana government also wants to diversify paddy through some schemes. In this research paper, a comparison of both the Kharif crops yield with monsoon rainfall distribution has been presented. At the same time, an attempt has also been made to show what has been the trends of rice crop and millet crop area in the last ten years.

**Objective**

- To highlight the trends of area under the crops of rice and millet in Haryana
- To highlight the relationship between maximum yield of rice and millet with different months of rainfall.
- To highlight the impact of monthly rainfall distribution on rice and millet crop yield in selected area during observation period.

## RESEARCH METHODOLOGY

The study was based on secondary data. The study was conducted on Sonipat district of Haryana. List of top ten rice producer districts has been prepared from the data base of Haryana Statistical Abstrct – 2023–24. Out of this list district Sonipat was selected on random basis. Data regarding rainfall, temperature (https://www.worldweatheronline.com), rice production, rice area and productivity of selected research area (for the year 2013–14 to 2022–23) have been collected from different published and unpublished source of Government officials.

**Research Model – 1**

Relative change (%)

$C\% = (x_2 - x_1) / x_1 * 100$

Where:

C%= Relative change (%)

$X_1$ = Value of base year (Bench mark Production/ Optimum rainfall per month)

$X_2$ = Value of basic years

Relative change is the indicator of difference of change in different values with respect to selected value (Rahul et al., 2025).

(*Limitation – Rice mainly depends on temperature and rainfall where other Wheater factors were assumed constant.*)

**Research Model – 2**

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5$$

$$\text{Yield} = \alpha + \beta_1 \text{ June} + \beta_2 \text{ July} + \beta_3 \text{ Aug} + \beta_4 \text{ Sept} + \beta_5 \text{ Oct}$$

**Hypothesis**

$H_0$: $\beta = 0$ (Corresponding months have no significant impact on yield (Rice/Millet)

$H_1$: $\beta \neq 0$ (Corresponding months have significant impact on yield (Rice/Millet)

**Statistical Tools**

Tools like Multivariate Regression, Percentage and Growth rate were used for processing the results from collected data.

**RESULTS**

**Part – I**

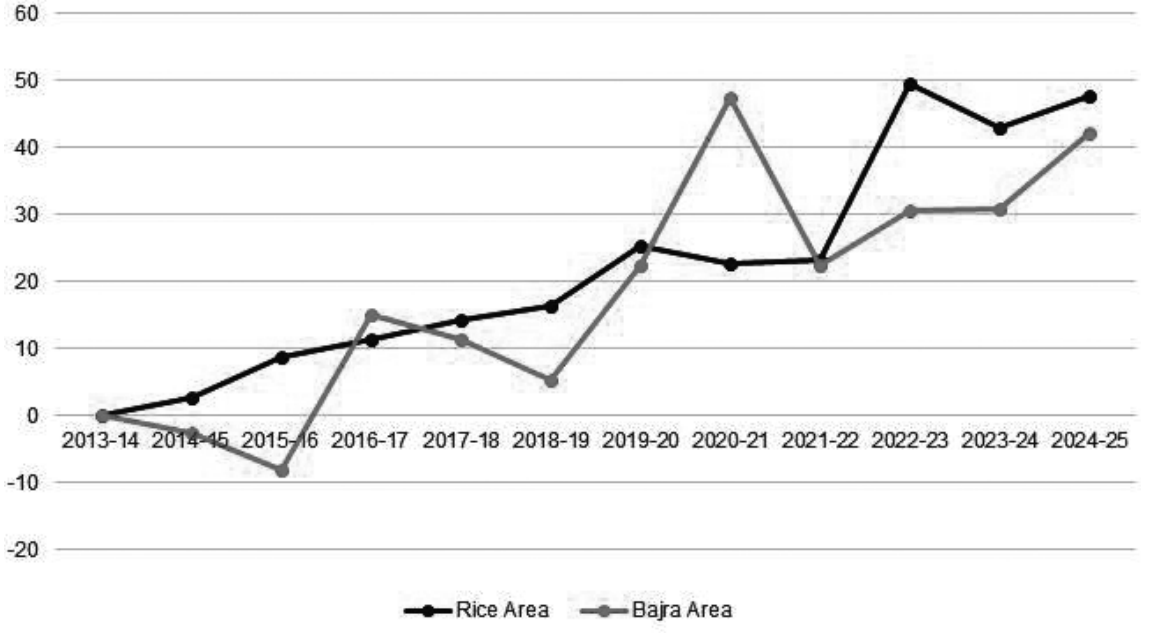
Table 1 and Graph 1 shows the trends of area of two major kharif crops (Rice and Millet) of selected area for ten years. Results shows that growth rate was high in Rice area as compare to Millet. During 2014–15 and 2015–16 Millet registered negative area growth, after 2019–20 we can observe sudden gain in Millet crop area from the year 2019–20 on wards. In these years rice area also got increasing trends in crop area. The results indicated positive impact of various schemes announced by state and central government. However,

**Table 1** Trends of Area under Crop of *Rice* and *Millet* in Haryana

| *Year* | *Rice Area* | *Millet Area* |
|---|---|---|
| 2013–14 | 0 | 0 |
| 2014–15 | 2.65 | –2.48 |
| 2015–16 | 8.76 | –8.19 |
| 2016–17 | 11.25 | 15.14 |
| 2017–18 | 14.31 | 11.41 |
| 2018–19 | 16.32 | 5.21 |
| 2019–20 | 25.32 | 22.33 |
| 2020–21 | 22.59 | 47.39 |
| 2021–22 | 23.23 | 22.33 |
| 2022–23 | 49.60 | 30.52 |
| 2023–24 | 42.85 | 30.77 |
| 2024–25 | 47.67 | 42.18 |

Figure shows the percentage growth rate.

*Data Source:* Different Volume of Haryana Statistical Abstracts and ministry of Agriculture of Haryana.




**Graph 1** Trends of Area under Crop of *Rice* and *Millet* in Haryana

*Data Source:* Different Volume of Haryana Statistical Abstracts and Ministry of Agriculture of Haryana.

the area growth rate of Rice was still more then Millet area growth rate in selected district.

**Part – II**

This section of paper presented the deviate production percentage from the bench mark year productivity and rainfall patterns of different months with respect to optimum rainfall. During the observation years, the year which has given the highest yield is considered as the bench mark year. The monthly rainfall distribution of bench mark year is assumed as the optimum rainfall distribution. The yield per hectare was higher (i.e. 2020, where yield per hectare was maximum for both rice and Millet crop, 3006 kg/hec (kilogram per hectare) and 2610 kg/hec. respectively. The basic purpose of this section was to highlight the relative change in productivity and rainfall patterns.

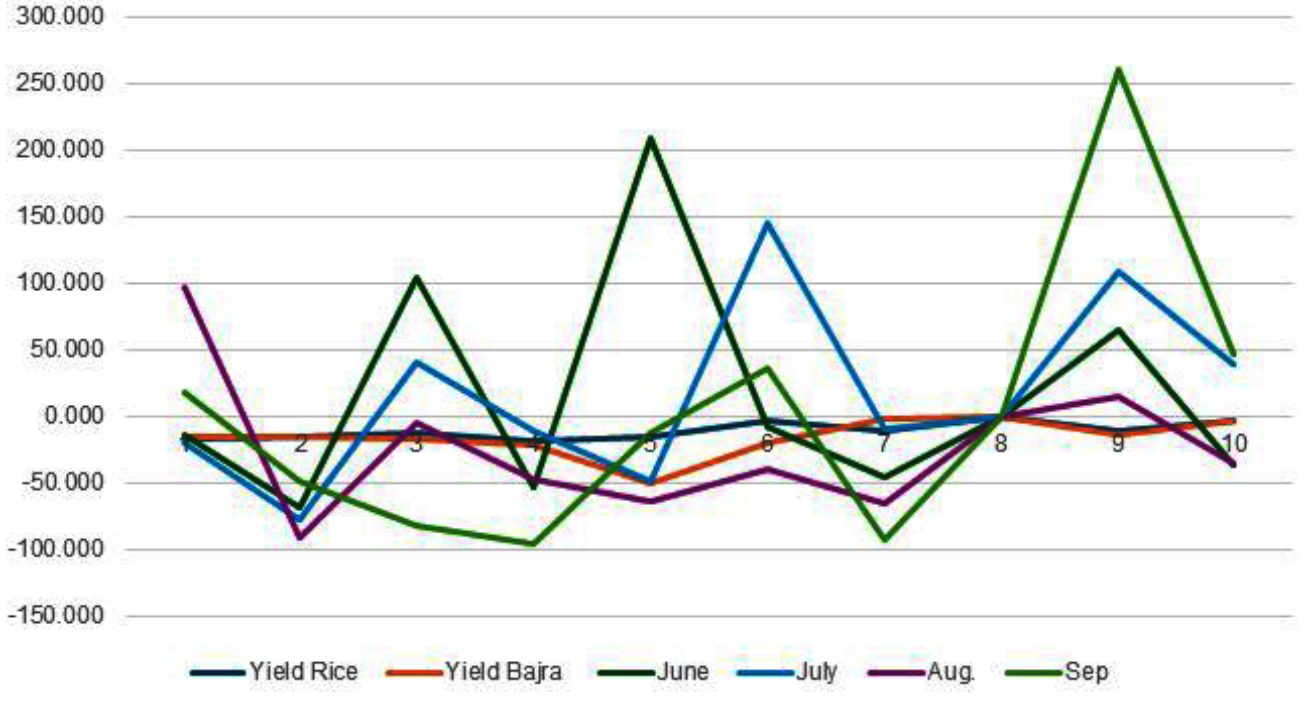
Table 2 shows relative change in productivity of Rice and Millet with respect to bench mark year and pattern

**Table 2** Relative Change in Productivity and Rainfall Pattern

| *Years* | *Yield Rice* | *Yield Millet* | *June* | *July* | *Aug.* | *Sep* |
|---|---|---|---|---|---|---|
| 2013–14 | –17.399 | –15.326 | –13.817 | –20.000 | 96.640 | 18.000 |
| 2014–15 | –15.635 | –15.326 | –69.555 | –77.813 | –90.977 | –49.000 |
| 2015–16 | –12.242 | –17.165 | 103.747 | 40.000 | –5.414 | –82.000 |
| 2016–17 | –19.561 | –22.146 | –54.333 | –11.250 | –47.418 | –96.000 |
| 2017–18 | –15.303 | –51.073 | 209.133 | –49.063 | –63.908 | –13.500 |
| 2018–19 | –3.360 | –19.693 | –8.665 | 144.375 | –40.261 | 35.000 |
| 2019–20 | –10.745 | –1.839 | –46.604 | –9.187 | –65.152 | –93.500 |
| 2020–21 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2021–22 | –10.978 | –14.559 | 65.105 | 108.438 | 14.499 | 260.000 |
| 2022–23 | –4.225 | –4.368 | –37.471 | 38.625 | –35.283 | 47.000 |

Figure shows the percentage change from selected year.

*Data Source:* Different Volume of Haryana Statistical Abstract.




**Graph 2** Relative Change in Productivity of Rice and Rainfall Pattern

*Data Source:* Different Volume of Haryana Statistical Abstract

of rainfalls. The maximum change was –3 percent to –19 percent in yield per ha in case of rice where it was –1 to –51 in case of Millet during selected years. The year wise productivity difference was high in Millet in case of Rice. In case of Rice productivity was lower 19 percent in 2016–17 from bench mark year, where it was 3 percent lower in 2018–19. During other year productivity was floating between these range. On the other hand, in case of Millet results shows that year 2017 reported less productivity as compare to bench mark year where productivity was almost similar in the year 2019 according to the results.

In case of rain the more variation in rainfalls as compare to productivity. The value of June rainfalls deviates –54 percent to +206 from assumed optimum rainfall. The variation was low in case of July and August rain as compare to June rain, it was maximum +144 to –77 and +90 to –90.98 in July and August respectively. In case of September rain, the negative variation was very less compared to high.

As explained earlier that there was more variation in rainfall as compare to productivity of both crops. In other words, it may be concluded from above results that during the study period the month wise rain deviation was very high, means there was no similar rain pattern in different selected months. In September months rain variation noted high as compare to other months of study periods.

**Part – III**

Rainfall Distribution and Impact on Rice production:

$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$

Yield = 2561.31 + –0.627 June + 0.972 July + –0.338 Aug + 0.0663 Sept

Table 3

| | *June* | *July* | *August* | *Sept.* |
|---|---|---|---|---|
| Coefficients | –0.627 | 0.972 | –0.338 | 0.066 |
| Std. error | 2.003 | 0.819 | 0.918 | 0.919 |
| t-stat | –0.313 | 1.187 | –0.36 | 0.072 |
| p-Value | 0.766 | 0.288 | 0.727 | 0.945 |

Results based on data collected by different volume of Statistical Abstract of Haryana.

Multiple R = 0.556, R-Square = 0.3094, F-Statics = 0.560, Adjusted R-Square = –0.243

Intercept = 2561.316348

Results of Multivariate Regression Analysis shows that there was not a similar impact of different months rainfalls on yield. June and August rainfalls of different years had negative impact on yield, where July and September rainfall reported positive impact on yield.

Results of R-Square shows that approximately 30.25 percent variance was occurred in dependent variable due to independent variables. Value of Multiple R indicated moderate positive relation between independent variables and dependent variable.

Since the P-Value of for all independent variables the regression coefficient is greater than 0.05. Hence, we retain the *Null Hypothesis*, which implies that the study did not find enough evidence to claim any significant impact of rainfall of any of the months on yield at 5 percent level of significant.

Finally, it may be concluded on the basis of Adjusted R-Square value that expected independent variables are not sufficient to predict the variance in dependent variable in case of rice production.

Rainfall Distribution and Impact on Millet production:

$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$

Yield = 2337.70 + – 7.528 June + 0.573 July + –0.876 Aug + 0.053 Sept

Table 4

| | June | July | August | Sept. |
|---|---|---|---|---|
| Coefficients | –7.528 | 0.573 | 0.876 | 0.0530 |
| Std. error | 2.922 | 1.196 | 1.342 | 1.342 |
| t-stat | –2.576 | 0.479 | 0.653 | 0.039 |
| p-Value | 0.049 | 0.652 | 0.542 | 0.969 |

Results based on data collected by different volume of Statistical Abstract of Haryana.

Multiple R = 0.776, R-Square = 0.603, F-Statics = 1.899, Adjusted R-Square = 0.285

Intercept = 2337.70

Results shows that there was high difference in the coefficient values of different independent variables on dependent variable, where results shows that June rainfall was negatively correlated means one unit increase in rainfall of June months leads –7.5 decrease in yield. On the other hand, July, August and September rainfalls were positively related with yield of Millet. The impact of September rainfall found less as compare to July and August rainfall. Results of R-Square shows

that approximately 60.3 percent variance was occurred in dependent variable due to independent variables. Value of Multiple R indicated high positive relation between independent variables and dependent variable.

The p value of regression coefficient for the month of June is less 0.05 (P = 0.049) so we reject the null hypothesis which implies that the rainfall of month June has significant impact on the yield of Millet.

Since the P-Value of the regression coefficient for the months, i.e. July, August and September is greater than 0.05. Hence, we retain the *Null Hypothesis*, which implies that the study did not find enough evidence to claim any significant impact of rainfall of any of these three months on yield at 5 percent level of significant. Where in case of June rainfall P-Value exhibit less than 0.05, that shows

Finally, it may be concluded on the basis of above result that expected independent variables are not sufficient to predict the variance in dependent variable in case of Rice and Millet production.

## CONCLUSION

Both Rice and Millet are main crops of Kharif season of selected study area. Where rice is more valuable crop but the sustainability due to Rice production also has to be taken into account. In the last few years, the Government has focused a lot on the alternate of Rice crop and importance has been given to millet grains. For this reason, both Rice and Millet become main crops of Kharif season. Kharif crop has a deep relation with rainfall because 80 percent of annual rainfall occurs in Kharif crop months only. What effect does rainfall distribution have on both the Kharif crops is an important issue.

There has been good growth in both the crops area in the last few years (2012–13 to 2023–24. This growth rate has been higher in the rice area, which shows that in the last few years people have preferred rice cultivation more than other crops in this season. After 2020, good growth has been observed in the rice area as well. The second part of the paper shows the change in yield of different crops and in which direction the change in rainfall pattern is taking place. There has been more change in the yield of other years than the bench mark yield of both the crops. While this change in case of Rice has been between 0 to –19 percent in the last 10 years, in case of millet this change is between 0 to –51 percent. If we look at lesser periods, 51 percent less production than the maximum yield has also been noticed in case of millet crop during the study period. Similarly, there has been a lot of change in rainfall during this period. If the rainfall for maximum yield is considered as optimum rainfall, then more variation has been observed in rainfall of other years than the optimum rainfall. This variation has been observed maximum in the rainfall of June and September months and least in August and July months. The third part of the paper shows the correlation of rainfall distribution with yield. It shows that the effect of different months rainfall on rice crop yield is less as compared to millet crop yield.

If we compare the results of both crops then we come to the conclusion that June rainfall was negatively correlated with both crops yields, the variation value was higher in case of Millet yield as compare to Rice yield. In case of July rainfall both tables indicated positive correlation of yield and rainfall of July month, where the value of coefficient was higher in case of Rice as compare to Millet. It is also observed from the results that rainfall of July impact higher on Rice yield then other months rainfall for both the crops. Future more in case of August month rainfall results shows that there was different response of August month rainfall on both crops. The coefficient value was negative for Rice and positive for Millet. Finally, September month rainfall had similar impact on both crops.

In case of R-Square value, after the comparison of both results, we can conclude that a higher level of variance occurred in Millet yield as compare to Rice yield due to rainfall of different month.

We can summarize the results by concluding that Rice crop yield was less impacted by rainfall distribution as compare to Millet crop yield.

## IMPLICATIONS AND FUTURE RESEARCH DIRECTION

This study is not free from limitations. Agricultural productivity is a subject of many independent variables but in the present study only one independent variable was examined, secondly each unit of area of crops did not get equal proportion of rainfall across the district. These multiformities were ignored and all data was treated as on equal weight.

The study proved very helpful in rainfall predication and in predicating expected rice and millet production. It will serve as the base work for making future policy for crop diversification and has good scope for future research also. Future scholars can take the study as a base and find out the impact other independent variables on the dependent variable (yield). This will make policy making easier for agriculture sector.

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