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Assessment of yield and yield attributes gap under irrigated and rainfed condition in rice crop for different agroclimatic zones of Chhattisgarh using DSSAT Simulation model

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Abstract

Validation of the simulated value under DSSAT models experiment was conducted during *kharif* season for different rice varieties viz., Swarna, Mahamaya, MTU-1010 and Karma Mahsuri to assess the yield and yield attributes gap. The DSSAT simulation model was validated for the different agroclimatic zones of Chhattisgarh. Crop simulation models are essential tools to design management practices to mitigate such adverse conditions. An experiment was carried out during 2014 in Department of Agrometeorology, IGKV, Raipur. DSSAT simulation model was used for validating soil, crop and weather management data from three agroclimatic regions and five cultivars. The production potentials of the five varieties were higher in irrigated condition as compared to rainfed condition. From the yield gap analysis, it was found that the yield gap between no fertilizer stress and with fertilizer 100:60:40 kg/ha was highest in all three zones both under irrigated and rainfed conditions. It was also found that the highest yield gap was found in Karma Mahsuri with 7.5, 9.7 and 9.4 t/ha at Raipur, Ambikapur and Jagdalpur respectively under irrigated condition. Under rainfed condition yield gap was 4.5, 4.7 and 4.6 t/ha in Karma Mahsuri under Raipur, Ambikapur and Jagdalpur respectively. It was also found that the yield gap varied from variety to variety with highest yield gap in Karma Mahsuri in both irrigated and rainfed conditions in all the three stations.

Keywords: DSSAT Simulation model, Production potential, Irrigated and Rainfed condition, Agroclimatic zones

Introduction

Rice (*Oryza sativa* L.) (2n=24) is the most important cereal crop that has been referred as “Global Grain” because of its use as prime staple food in about 100 countries of the world. In world, rice has occupied an area of 160.6 million hectares, with a total production of 738.20 million tonnes and productivity of 3424.41 kg/ha (FAO, 2015). Chhattisgarh popularly known as Rice Bowl of India” occupies an area around 37.73 lakh hectares with the production of 60.28 lakh tonnes and productivity 1597 kg/ha (Anonymous, 2015) [4]. Rice being climatically the most adaptable cereal, it is grown over a large spatial domain and wide range of landscape types. With such a large variation in landscapes and climates in the rice-growing regions of India, a large number of unique paddy farming methods have also been evolved, based on farming type (irrigated, rainfed, deepwater), crop management (single crop, multi crop), and seasonality (wet season, dry season). Depending on the location, Indian rice is grown in the *kharif* (summer, wet) or *rabi* (winter, dry) seasons, or both. *Kharif* rice accounts for over 85 per cent of the total rice production in the country.

Crop simulation models are useful to assess the yield gap of a crop in a set of given conditions. DSSAT is the most popular dynamic crop simulation model and CERES- rice model is used for assessing the yield gap of rice under a given set of conditions. One of the main advantages of crop model application is the possibility to use them under various weather and soil conditions and under irrigated and rainfed condition in different regions of the Chhattisgarh. One of the important pre-conditions of the applications of dynamic model is the evaluation of the model reliability in reproducing the real conditions at the given place and time (Penning de Varies 1977, Addiscot *et al.* 1995).

Material and Methods

The objectives of the study included the validation and evaluation of the CERES-Rice model for three agroclimatic zones. The validation and evaluation process consists of the following steps:

1. Collection (Observation or measurement) of the experimental data (anthesis, maturity dates and grain yields),
2. Collection of weather data at three different agroclimatic zones.

The CERES-Rice model is no exception. These coefficients are crucial because they strongly influence the simulation of growth and development of the crop. The CERES-Rice model uses eight genetic coefficients viz., P_1, P_2O, P_2R, P_5, G1, G2, G3 and G4. The eight coefficients are worked out by conducting field experiment during *Kharif 2014* and for IR36; they were default in the model.

Table 1: The genetic coefficients for the five varieties

Varieties	P1	P2R	P5	P2O	G1	G2	G3	G4
IR36	470	149	400	11.7	68	0.023	1	1
Swarna	541	150	523	11.5	79	0.019	1	1
Mahamaya	429	150	302	11.5	56	0.026	1	1
MTU1010	399	150	329	11.5	61	0.023	1	1
Karma Mahsuri	478	150	364	11.5	113	0.019	1	1

The details of these genetic coefficients are as follows:

- Juvenile phase coefficient P1
- Critical photo period P2O
- Photoperodism coefficient P2R
- Grain filling duration coefficient P5
- Spikelet number coefficient G1
- Single grain weight G2
- Tillering coefficient G3
- Temperature tolerance coefficient G4

Required inputs

1. Computation of solar radiation.
2. Preparation of weather files for model.
3. Soil data.

Daily weather data

The daily weather parameters required for the study were collected from thedata base of the Department of Agrometeorology, IGKV, Raipur. The data bases available for stations are as follows:

S. No	Station Data base	Data base
1	Raipur	1981-2013
2	Ambikapur	1995-2013
3	Jagdalpur	1993-2013

During the crop growth period the maximum temperature ranged from 31 °C to 39 °C whereas minimum temperature ranged from 24.3 °C to 28 °C. The total rainfall recorded 1042 mm, the morning relative humidity varied from 65 to 94 per cent whereas in after noon it varied from 41 to 74 per cent. The soil of the experimental field was clay loam with moderately coarse texture of vertisol group locally known as "*Kanhar*." The soil was neutral in reaction and had low phosphorous medium nitrogen and potassium content. Prior to the present experiment, the field was cropped with rice (*Oryza sativa* L.) during *kharif* and wheat (*Triticum aestivum* L.) during *rabi* in the preceeding three years.

Results and Discussion

For assessing the production potential of four important varieties grown in Chhattisgarh state namely, Swarna, Mahamaya, MTU1010, Karma Mahsuri, field experiment was conducted with three dates of sowing for evaluating the genetic coefficients of these varieties. The genetic coefficients of IR36, an international variety, were collected from the DSSAT simulation programme. The genetic coefficients of the five varieties are presented in the earlier chapter (materials and method).Using these genetic coefficients of the five rice varieties the production potentials in three agroclimatic zones of Chhattisgarh state in irrigated as well as rainfed conditions were worked out. Also the yield attributing characters of these varieties under potential conditions were also worked out using DSSAT (CERES), a dynamic crop simulation model. The results are discussed below.

1. Yield gap analysis

1.1. Fertilizer dose yield gap

Simulation was run with DSSAT model to know yield gap between no fertilizer stress and with 100:60:40 NPK both under irrigated and rainfed conditions for three stations namely Raipur, Ambikapur, Jagdalpur. The results are shown in Table 1.1, 1.2 and 1.3. It can be seen from the Tables that under irrigated condition yield gap between no fertilizer stress and with 100:60:40 kg NPK was varying. In Karma Mahsuri it was highest 7.5t/ha while it was lowest in MTU-1010 with 5.78 t/ha while in other varieties varied from 5.95 to 6.44 t/ha under irrigated condition. Under rainfed condition, the highest yield gap was observed for Karma Mahsuri followed by Mahamaya. In case of Karma Mahsuri the yield gap was 4.57 t/ha while the lowest yield gap was observed is Swarna variety with 3.65 t/ha. In IR-36, Mahamaya and MTU1010 yield gap was 4.22, 4.56 and 4.37 t/ha respectively.

At Ambikapur the yield gap was much higher than at Raipur under irrigated condition with yield gap between no fertilizer stress and with 100:60:40 NPK. Karma Mahsuri showed highest yield gap of 9.76 t/ha while MTU-1010 showed 7.25 t/ha yield gap. For IR-36 the yield gap was also higher with 8.27 t/ha. In rainfed condition also Karma Mahsuri showed highest yield gap of 4.78 t/ha with no fertilizer stress and with 100:60:40 NPK /ha. This is followed by MTU-1010 with 4.64 t/ha and Mahamaya 4.61 t/ha. Swarna showed lowest yield gap of 3.48 t/ha in Ambikapur condition.

In Jagdalpur also Karma Mahsuri showed highest yield gap of 9.45 t/ha followed by IR36 with 7.83 t/ha under irrigated condition. In other varieties it varied from 6.60 to 7.25 t/ha. Under rainfed condition the yield gap at Jagdalpur was also highest in with 4.62 t/ha followed by MTU1010 with 4.25 t/ha. The lowest yield gap was found in Swarna 2.25 t/ha and this is followed by Mahamaya with 3.37 and IR36 with 3.43 t/ha.

From above analysis it was found that yield gap between no fertilizer stress and with 100:60:40 NPK/ha was highest in all the three stations both under irrigated and rainfed condition. This suggests that the 100:60:40 recommended fertilizer dose is less under both irrigated and rainfed condition. It is necessary to work out the optimum fertilizer dose to achieve the potential yield both under irrigated and rainfed conditions. It was also found that the yield gap varied from variety to variety with highest yield gap in Karma Mahsuri in both irrigated and rainfed conditions in all the three stations. This also suggests that Karma Mahsuri is more fertilizer hungry when compared to others. It is therefore necessary to workout fertilizer dose for each individual variety separately.

1.2. Irrigated and Rainfed yield gap

The yield gap between irrigated and rainfed rice between no fertilizer stress and with 100:60:40 NPK/ha was analysed using DSSAT simulation model for the five rice varieties at the three stations. The results are shown in Table 2.1, 2.2 and 2.3. It can be seen that the potential yield gap between irrigated and rainfed condition is 2.66 t/ha. In case of IR36 and Swarna it was 4.25 t/ha. The lowest yield gap was found in Mahamaya 14.5 q/ha followed by MTU1010 with 1.54 t/ha at Raipur.

In Karma Mahsuri the potential yield gap in irrigated and rainfed condition is 3.10 t/ha. Therefore, it is can be suggested that there is a very good scope to increase the productivity of rice with adequate fertilizer dose even under rainfed condition. In case of recommended fertilizer dose of 100:60:40 kg/ha NPK, the potential yield gap between irrigated and rainfed condition is very low when compared to with no fertilizer stress. Thus, even with 100:60:40 kg/ha NPK the recommended dose of fertilizer is sufficient to tap the potential under Raipur condition. In Ambikapur also same pattern was observed but higher yield gap with 100:60:40 kg/ha NPK. Thus, better management can reduce yield gap under irrigated and rainfed condition with 100:60:40 kg NPK/ha. In case of Jagdalpur the potential yield gap with 100:60:40 Kg NPK/ha between irrigated and rainfed condition is almost negligble. The potential yield gap was also very low when compared to other stations, At Jagdalpur the rainfall quantum and duration is higher when compare to other two stations. Thus there is good scope for improve the productivity of rice even under rainfed conditions with recommended dose of fertilizer.

Thus, from the above analysis it was found that the yield gap between no fertilizer stress and with recommended practise of 100:60:40 kg NPK/ha suggests that:

1. The recommended dose of fertilizer is not sufficient to obtain the potential yield in both irrigated and rainfed condition in all the station.
2. The potential yield gap between irrigated and rainfed condition with no fertilizer stress and with 100:60:40 kg NPK/ha reveal that even under rainfed condition the potential yield could be achieved with the recommended dose of fertilizer with better management under rainfed condition. Thus, it is necessary to conduct location specific and varietal trials to recommend suitable fertilizer dose for each variety and for each location.

Table 1.1: Yield gap between irrigated and rainfed rice with no fertilizer stress and with 100:60:40 NPK/ha dose under Raipur

Variety	Irrigated yields (Kg/ha)			Rainfed yields (Kg/ha)		
	With no fertilizer stress	With 100:60:40	Yield gap	With no fertilizer stress	With 100:60:40	Yield gap
IR36	10029	3584	6445	7363	3135	4228
Swarna	10331	4059	6272	6072	2414	3658
Mahamaya	9236	3285	5951	7785	3223	4562
MTU1010	8949	3167	5782	7401	3029	4372
Karma Mahsuri	10883	3362	7521	7782	3203	4579

Table 1.2: Yield gap between irrigated and rainfed rice with no fertilizer stress and with 100:60:40 NPK/ha dose under Ambikapur

Variety	Irrigated yields (Kg/ha)			Rainfed yields (Kg/ha)		
	With no fertilizer stress	With 100:60:40	Yield gap	With no fertilizer stress	With 100:60:40	Yield gap
IR36	11402	3130	8272	7347	2781	4566
Swarna	11129	3562	7567	5742	2261	3481
Mahamaya	10723	2967	7756	7210	2598	4612
MTU1010	10078	2827	7251	7159	2516	4643
Karma Mahsuri	12781	3018	9763	7621	2845	4776

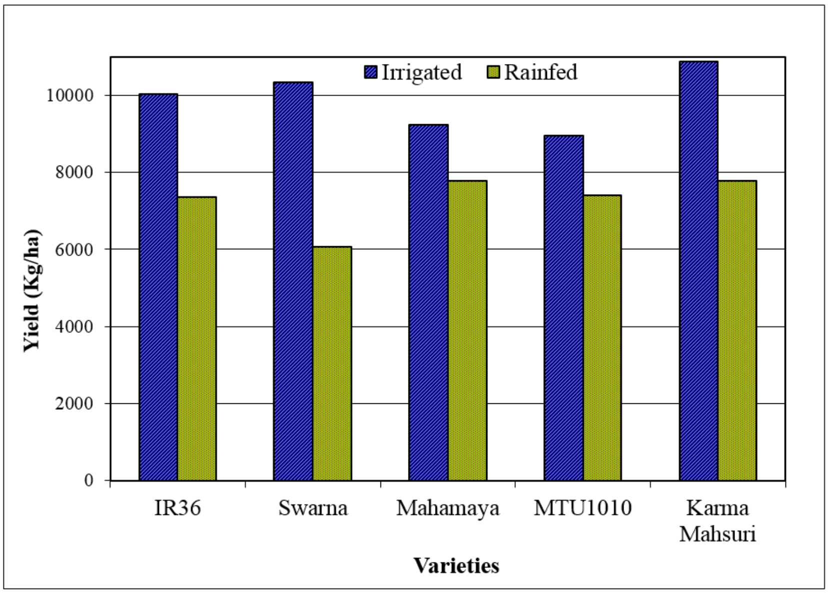
Table 1.3: Yield gap between irrigated and rainfed rice with no fertilizer stress and with 100:60:40 NPK/ha dose under Jagdalpur

Variety	Irrigated yields (Kg/ha)			Rainfed yields (Kg/ha)		
	With no fertilizer stress	With 100:60:40	Yield gap	With no fertilizer stress	With 100:60:40	Yield gap
IR36	11370	3539	7831	9848	3523	6325
Swarna	11334	3830	7504	8122	3809	4313
Mahamaya	10594	3337	7257	9766	3336	6430
MTU1010	9820	3211	6609	9107	3209	5898
Karma Mahsuri	12780	3324	9456	10327	3315	7012

Table 2.1: Yield gap between irrigated and rainfed potential rice yields and with 100:60:40 NPK/ha fertilizer dose under Raipur

Variety	Potential yield (Kg/ha)			100:60:40 (Kg/ha) N:P:K		
	Irrigated	Rainfed	Yield gap	Irrigated	Unirrigated	Yield gap
IR36	10029	7363	2666	3584	3135	449
Swarna	10331	6072	4259	4059	2414	1645
Mahamaya	9236	7785	1451	3285	3223	62
MTU1010	8949	7401	1548	3167	3029	138
Karma Mahsuri	10883	7782	3101	3362	3203	159

- **Potential rice yield condition**



- **B 100:60:40 Kg NPK/ha condition**

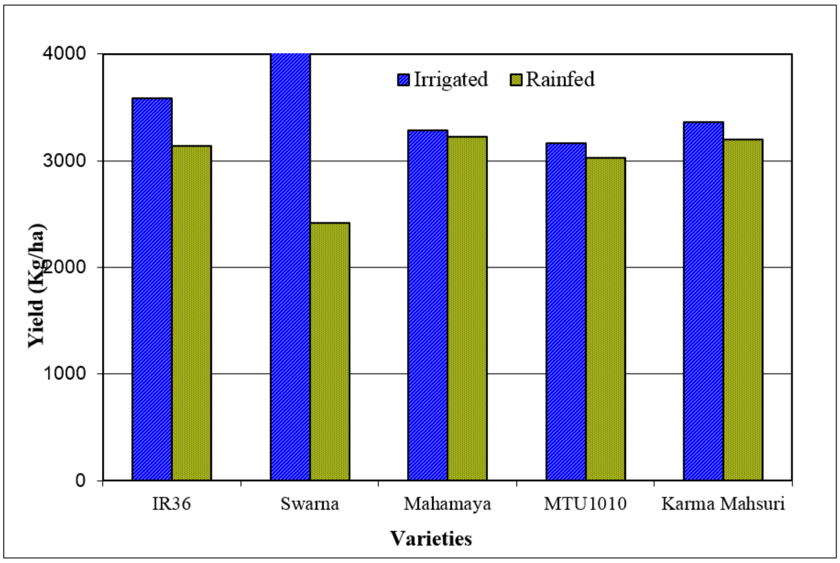
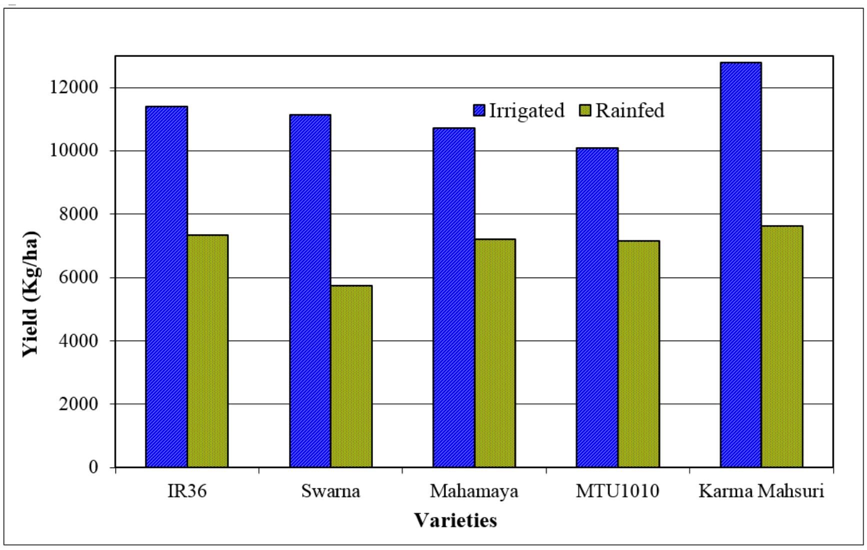


Fig 1.1: Yield gap between irrigated and rainfed potential rice yields and with 100:60:40 kg NPK/ha fertilizer dose under Raipur.

- **Potential rice yield condition**



- **100:60:40 Kg NPK/ha condition**

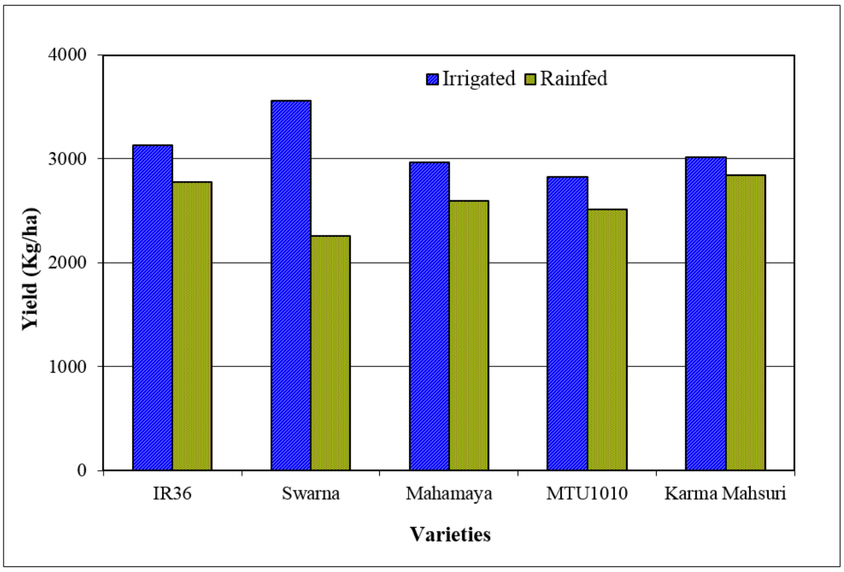
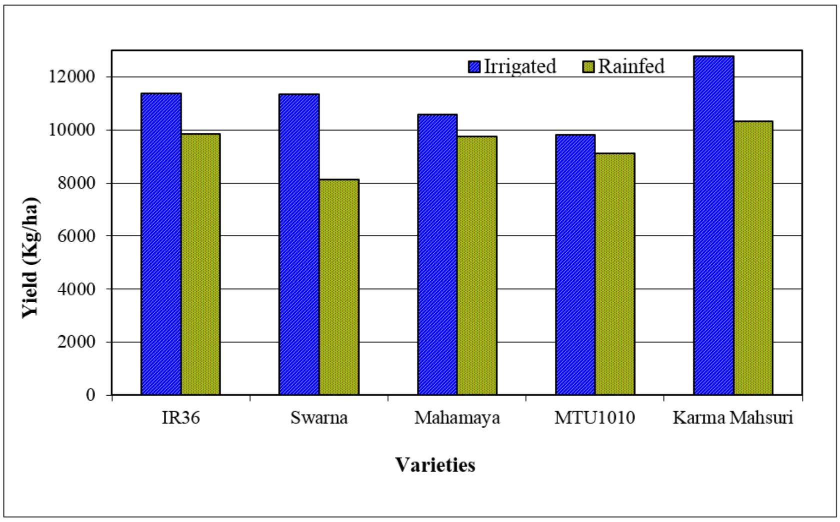


Fig 1.2: Yield gap between irrigated and rainfed potential rice yields and with 100:60:40 kg NPK/ha fertilizer dose under Ambikapur

- **Potential rice yield condition**



- **100:60:40 Kg NPK/ha condition**

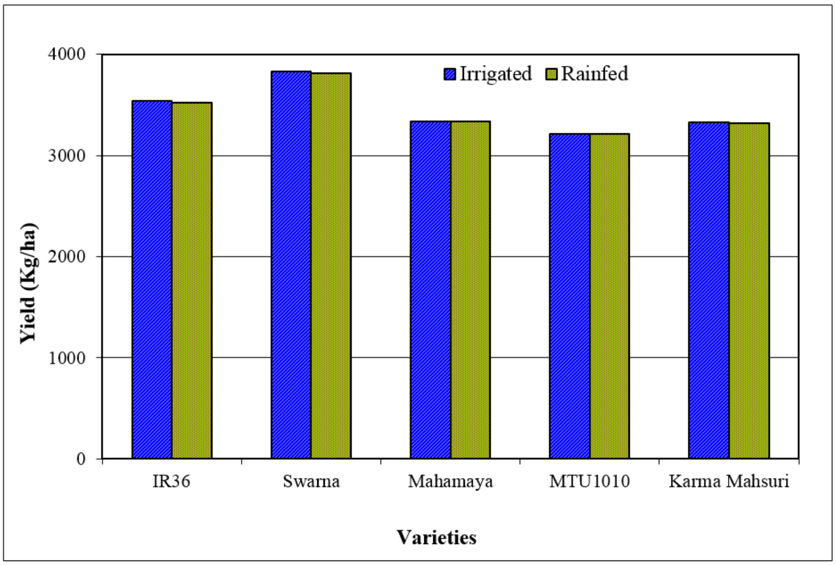


Fig: 1.3: Yield gap between irrigated and rainfed potential rice yields and with 100:60:40 kg NPK/ha fertilizer dose under Jagdapur.

Table 2.2: Yield gap between irrigated and rainfed potential rice yields and with 100:60:40 NPK/ha fertilizer dose under Ambikapur.

Variety	Potential yield (Kg/ha)			100:60:40 (Kg/ha) N:P:K		
	Irrigated	Rainfed	Yield gap	Irrigated	Unirrigated	Yield gap
IR36	11402	7347	4055	3130	2781	349
Swarna	11129	5742	5387	3562	2261	1301
Mahamaya	10723	7210	3513	2967	2598	369
MTU1010	10078	7159	2919	2827	2516	311
Karma Mahsuri	12781	7621	5160	3018	2845	173

Table 2.3: Yield gap between irrigated and rainfed potential rice yields and with 100:60:40 NPK/ha fertilizer dose under Jagdalpur.

Variety	Potential yield (Kg/ha)			100:60:40 (Kg/ha) N:P:K		
	Irrigated	Rainfed	Yield gap	Irrigated	Unirrigated	Yield gap
IR36	11370	9848	1522	3539	3523	16
Swarna	11334	8122	3212	3830	3809	21
Mahamaya	10594	9766	828	3337	3336	1
MTU1010	9820	9107	713	3211	3209	2
Karma Mahsuri	12780	10327	2453	3324	3315	9

Conclusion

From the yield gap analysis, it was found that the yield gap between no fertilizer stress and with fertilizer 100:60:40 kg/ha was highest in all three zones both under irrigated and rainfed conditions. It was also found that the highest yield gap found in Karma Mahsuri with 7.5, 9.7 and 9.4 t/ha at Raipur, Ambikapur and Jagdalpur respectively under irrigated condition. Under rainfed condition yield gap was 4.5, 4.7 and 4.6 t/ha in Karma Mahsuri under Raipur, Ambikapur and Jagdalpur respectively. Study on potential yield gap under recommended fertilizer dose 100:60:40 indicated that between irrigated and rainfed conditions, yield was very low when compared to no fertilizer stress. It was also found that highest yield gap in potential yield was 4.2, 5.3 and 3.2 t/ha at Raipur, Ambikapur and Jagdalpur respectively. Similarly in terms of recommended dose under irrigated and rainfed condition the highest yield gap was found in Swarna variety 1.6, 1.3 and 2.1 t/ha for three zones respectively. However with 100:60:40 kg/ha NPK the recommended dose of fertilizer is sufficient to tap the potential under Raipur condition. The potential yield gap was also low when compared to other stations.

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