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Crop planning based on rainfall probability for Bhadrak district of Odisha

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Abstract
The knowledge and information on the rainfall dynamics and its distribution over the cropping season are very important for selection of crop varieties and choice of cropping pattern. Block wise historical rainfall data of 23 years (1995 to 2017) of Bhadrak District were collected and processed by using Weather cock software which revealed that the total mean annual rainfall of the district is 1431 mm. Bhadrak receives almost 70% of mean annual rainfall during SW monsoon. Monsoon starts effectively from 24 SMW (Standard Meteorological Week) (12 June to 15th June) in Bhadrak district and remain active up to 41 SMW (9th October to 13th October). Therefore, we expected good monsoon shower for about 17 weeks (24th to 41th SMW) in the region. The initial rainfall probability {P (W)} of getting 20 mm rainfall per week was >30% during 22 SMW at Bhadrak district, hence, field preparation should be done during this period. The initial as well as conditional probability of wet week followed by wet week {P (W/W)} of getting 20 mm rainfall was more than 50% in 23rd SMW, this week is more suitable for sowing of crops. During 44th to 46th SMW (29th Oct. – 18th November) probability of getting 10 mm rainfall per week was more than 30 per cent. This period is suitable for land preparation and sowing of *rabi* crops. As *rabi* irrigated area of the district is only 20.1% and rainfed cropped area limited to 5.2%, vast area (74.7%) remains fallow after *kharif* crops. Proper crop planning with suitable water conservation measures are needed to be adopted to enhance the acreage, production and productivity *rabi* crops of the district.

Keywords: weather cock, CV, SW monsoon, SMW, *kharif*, *rabi*

Introduction
Rainfall is the single most important factor in crop production programme. Among the climatic factors, rainfall is of greatest concern to the farmers in rainfed agriculture. The variation of monsoonal and annual rainfall in space and time are well known and this inter-annual variability of monsoonal rainfall has considerable impact on agricultural production. Around 60 percent of the Indian agriculture is rain dependent, distress prone and vulnerable to climate. Climatic variability, particularly rainfall is the major factor influencing the agricultural productivity and sustainability in the tropics. The establishment of start, end and length of the growing season and the patterns of dry and wet spells throughout the season is suitable information for the agricultural planning and farm management processes comprising land preparation, crop planting, fertilizer and other agro-chemical applications, weeding, harvesting and post-harvest management. Odisha (17.49´N to 22.34´N and 81.27´E to 87.29´E), an eastern Indian province, is mainly an agrarian state where about 70 percent of the population is engaged in agricultural activities and 50 percent of the state's economy comes from agricultural sector. Bhadrak district falls under North Eastern Coastal Plain Zone of Odisha which covers 29 blocks of Balasore, Bhadrak and Keonjhar districts. The total geographical area of the district is 2, 50,000 ha. The net sown area in the district is 1, 73,000 ha. The total cultivable land in the district is 1, 74,063ha and irrigated area is 1, 11,000ha. Paddy is the principal crop of the district and is cultivated in 1, 64,000 ha in *Kharif* and 14,600 ha in *Rabi*. Lying on the coastline of the state of Odisha, the topography of the district of Bhadrak is principally affected by the sea.

Materials and Methods
Rainfall characteristics and rainfall variability
Block wise daily rainfall data were used to calculate the rainfall characteristics. Mean annual, seasonal and monthly rainfall variability were found out by analysing rainfall block wise over

a period of 23 years. The data were processed by using Weather cock. "Rainy Day.exe" module was used to analyse the rainfall data. The mean rainfall, standard deviation (SD) and Coefficient of variation (CV) for each data series were determined. The variability of the annual, seasonal and monthly rainfall values are indicated by standard deviation (SD) and Coefficient of variation (CV).

$$\mu = \frac{Sum\ of\ all\ observations}{Number\ of\ obseravtions} \quad \text{(Eq.1)}$$

$$\sigma = \sqrt{\frac{\sum(X-\mu)^2}{n-1}} \quad \text{(Eq. 2)}$$

$$CV = \frac{Standard\ deviation}{Mean} \times 100 \quad \text{(Eq. 3)}$$

Where μ is arithmetic mean; σ is Standard deviation; X is actual value of any weather element; and 'n' is number of years.

Initial and conditional probabilities (Markov–chain model)

Simple criterion related to sequential phenomenon like dry and wet spell was used for analysing rainfall data to obtain specific information needed for crop planning and for carrying out agricultural operations. Rainfall of 20 mm per week is adequate for all the growth stages of all the crops grown. Thus, if in a given week the rainfall received is less than 20 mm that week can be designated as a dry week and vice versa. On the basis of this criterion each week was categorised as a dry week and wet week and respective probabilities were calculated by Markov chain model procedure.

Initial probability

P (D) = F (D)/N (Eq. 4)
P (W) = F (W)/N (Eq. 5)

Where, P (D) = probability of the week being dry, F (D) = frequency of dry weeks, P (W) = probability of the week being wet, F (W) = frequency of wet weeks, and N = total number of years of data being used.

Conditional probabilities

P (DD) = F (DD)/F (D) (Eq. 6)
P (WW) = F (WW)/F (W) (Eq. 7)
P (WD) = 1 – P (DD) (Eq. 8)
P (DW) = 1 – P (WW) (Eq.9)

Where, P(DD) = probability of a week being dry preceded by another dry week, F(DD) = frequency of dry week preceded by another dry week, P(WW) = probability of a week being wet preceded by another wet week, F(WW) = frequency of a wet week preceded by another wet week, P(WD) = probability of a wet week preceded by a dry week, and P(DW) = probability of a dry week preceded by a wet week.

Consecutive dry and wet week probabilities

P(2D) = P(DW1)×P(DDW2) (Eq. 10)
P(3D) = P(DW1)×P(DDW2)×P(DDW3) (Eq. 11)
P (2W) = P (WW1) ×P (WWW2) (Eq. 12)
P (3W) = P (WW1) ×P (WWW2) ×P (WWW3) (Eq. 13)

Where, P(2D) = probability of 2 consecutive dry weeks starting with the week, P(DW1) = probability of the first week being dry, P(DDW2) = probability of the second week being dry, given the preceding week being dry, P(3D) = probability of 3 consecutive dry weeks starting with the week, P(DDW3) = probability of the third week being dry, given the preceding week dry, P(2W) = probability of 2 consecutive dry weeks starting with the week, P(WW1) = probability of the first week being wet, P(WWW2) = probability of the second week being wet, given the preceding week being wet, P(3W) = probability of 3 consecutive wet weeks starting with the week and P(WWW3) = probability of the third week being wet, given the preceding week wet.

Thresholds of rainfall for Crop planning using Initial and conditional probabilities

For the purpose of agricultural planning, we have applied Markov Chain model by choosing 10, 20, 40 and 80mm/week as threshold limits. These threshold levels were considered as adequate for the crop activities such as land preparation (10mm), crop planting or sowing (20mm), and application of fertilizer and/or weeding (40mm).

According to Reddy, if a given week 'i' of a given year received more than 20mm/week at more than 50% (W/W) threshold level, then week 'i' is the right time for planting. If weeding/fertilizer application is to be carried out in week 'i' then the week should have at least 75% (W/W) probability at 40mm/week. If the interest is when we should not apply fertilizer/pesticides, then one can use the probability estimate at 80mm/week. If fertilizer and/or insecticides/pesticides are applied on week 'i' then W should not exceed 25% probability level at 80mm/week. Rajendram and Sivasami applied the same threshold limits to estimate the weekly rainfall probabilities over Batticaloa, Sri Lanka.

Results and Discussion

Rainfall characteristics and rainfall variability

Annual Rainfall and rainy days

The mean annual rainfall of the district was found to be 1431 mm (Table 1). Highest rainfall was received in the block Basudevpur (1849mm) while Bhandaripokhari block received the lowest amount of rainfall (1250mm).Variability of the district annual rainfall was 21% to 33% (Table 1). Thus blocks having CV less than 25% can be considered to be receiving rainfall that is highly dependable. The blocks coming under this category are Bhadrak, Bonth and Chandbali. The remaining four blocks (Bhandaripokhari, Basudevpur, Dhamnagar, and Tihidi) are having CV greater than the threshold indicating that there is high variability in the amount of rainfall received by these blocks over years. So, a greater part of the district has the risk in rainfed farming.

Pasupalak (2015) [3], reported that the variability of annual rainfall in Odisha was 21%. Eight districts had high variability (>23%), while 10 districts had low variability (<20%). Variability was maximum (25%) in Sonepur district and minimum (16%) in Sundargarh district. Present results confirm the results of Pasupalak (2015) [3] for the Bhadrak district.

Table 1: Block wise mean annual rainfall with standard deviation and CV (%)

Block	Mean(mm)	SD	CV (%)
Bhadrak	1461	308	21
Bhandaripokhari	1250	362	28
Basudevpur	1849	575	31
Bonth	1320	320	24
Chandbali	1500	370	24
Dhamnagar	1330	445	33
Tihidi	1308	385	29

Monthly Rainfall

Highest mean monthly rainfall in the district was in the month of July (286 mm) (Table 2). It was followed by August with 271 mm and September 238 mm. December was the month of the lowest rainfall (4mm). Monthly rainfall variability was maximum in March (48%) followed by December (29%), while minimum in the month of June and July (11%) followed by August (13%). Four out of twelve months namely, January, June, July and August had low variability (<20%) of monthly rainfall. Monthly rainfall variability was high (>20%) in the month of February, March, April, May, September, October, November and December (Table 2). Monthly rainfall varies from region to region and the highest rainfall giving month may be July or August.

Rainfall characteristics of the Cauvery basin shows that, the coefficient of variation is highest in July (100%), followed by June (97.96%), December (97.96%) and January (78.48%) and the least during October (15.19%) and September (23.77%). Significant relationship between SD and CV has been observed during the months of highest rainfall (July and June) (Sawant S. *et al*. 2015) [6].

Seasonal Rainfall

The district average SW monsoon rainfall is 1009mm±281 mm. Basudevpur block had the maximum (1257 mm) and Tihidi block had minimum (893 mm) of monsoon rainfall. Bhadrak receives almost 70% of mean annual rainfall during SW monsoon (Table 3). It was thus clear that SW monsoon accounts for a major part of rainfall distribution out of all the seasons. During SW monsoon, variability of rainfall was 24-33%. Lowest (21 mm) amount of rainfall was received during winter but maximum variability (125%) was observed during this period. Rainfall variability varied from 81% to 117% during post-monsoon and 41% to 72% in summer season (Table 3). The CV of seasonal rainfall except South west monsoon is higher than the threshold (50% for seasonal rainfall).

The summer monsoon rainfall over northeast India showed characteristic spatial and temporal variability due to the interaction of basic monsoon flow with orography and the synoptic scale systems developing over Indian region (Mohapatra *et al*. 2011) [2].

In a study conducted at Directorate of Water Management by Mandal *et al*., 2013 for Daspalla region of Odisha, it was observed that total annual rainfall in Daspalla region was 1509.2 mm with 14.8% CV. SW monsoon delivers about 75.7% of annual rainfall, winter season contributes 3.1%, and 10.8% & 10.4% of the total annual rainfall occurred during pre- and post-monsoon season, respectively.

Table 2: Mean monthly rainfall (mm) with standard deviation (mm) and CV (%)

Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bhadrak	9	14	37	54	160	238	347	345	326	275	36	4
Bhandaripokhari	10	9	9	32	95	195	269	242	223	141	18	3
Basudevpur	11	15	19	49	116	220	289	272	244	188	29	5
Bonth	11	14	14	32	97	184	288	269	225	157	21	4
Chandbali	12	6	19	33	91	213	283	307	264	221	44	3
Dhamnagar	7	7	17	46	111	187	267	266	200	193	22	2
Tihidi	10	11	16	48	117	178	249	239	226	177	31	2
District Mean	10	12	18	42	113	198	286	271	238	184	26	4
SD	2	3	9	10	23	22	31	35	41	44	6	1
CV (%)	15	26	48	22	20	11	11	13	17	24	25	29

Table 3: Mean seasonal rainfall with standard deviation and CV (%)

Block	Monsoon			Postmonsoon			Winter			Summer		
	Mean (mm)	SD (mm)	CV%	Mean (mm)	SD (mm)	CV%	Mean (mm)	SD (mm)	CV%	Mean (mm)	SD (mm)	CV%
Bhadrak	1026 (70%)	253	24	223 (15%)	230	103	26 (1.7%)	30	114	185 (12%)	76	41
Bhandaripokhari	930 (74%)	256	27	163 (13%)	170	104	19 (1.5%)	27	138	137 (10%)	84	61
Basudevpur	1257 (68%)	376	29	315 (17%)	281	89	23 (1.2%)	27	116	251 (11%)	154	61
Bonth	967 (73%)	240	24	183 (13%)	172	93	25 (1.8%)	31	124	143 (10%)	89	62
Chandbali	1069 (71%)	299	28	269 (17%)	220	81	18 (1.2%)	21	119	143 (9%)	78	54
Dhamnagar	921 (69%)	246	26	218 (16%)	256	117	14 (1%)	22	155	176 (13%)	127	72
Tihidi	893 (68%)	321	36	211 (16%)	148	70	21 (1.6%)	36	154	182 (14%)	75	40
District Mean	1009 (70%)	284	27	226 (15%)	211	93	21 (1.4%)	27	131	174 (12%)	97	55

Crop planning

Rice is the principal *kharif* crop sown in the district covering more than 95% area followed by Jute and Sugarcane. During *rabi* season Greengram, Blackgram, Mustard, Groundnut, Sunflower, Sesame, Potato, Onion and Cole crops are grown.

In Bhadrak district, out of 1, 68,167 ha of *kharif* cultivated area, only 42,462 ha is covered in *rabi* season, which is about 25%, while under *rabi* rainfed situation, the crop coverage is only 14.2%. Rice- green gram, Rice- black gram, Rice-groundnut are the major cropping system followed in the district. So there is enough scope to increase pulse area through *paira* cropping by taking 120-130 days duration rice varieties in *kharif* season.

Crop planning based on Initial and Conditional Rainfall Probability *Kharif* (Monsoon)

The initial rainfall probability {P (W)} of getting 20 mm rainfall per week was >30% during 22 SMW (Table 4) at

Bhadrak district and hence, field preparation should be done during this period. The pre-monsoon rain can be utilized for summer ploughing, sowing dhaincha and seed bed preparations. The initial as well as conditional probability of wet week followed by wet week {P (W/W)} of getting 20 mm rainfall was more than 50% in 23 SMW (Table 5). Therefore, this week is more suitable for sowing of direct seeded low land rice. Nursery preparation of rice can also be planned. Further delay in sowing may cause very low productivity and even crop failure. Nurseries for transplanted paddy can be sown either in 23 and 24SMW (4th – 17th June) with the pre-monsoon showers which seems to be sufficient to bear the normal soil moisture range and afford good germination. The direct sown paddy and paddy nurseries will be ready for further cultural operation and transplantation with the onset of monsoon (24 to 25 SMW). The transplantation of paddy should be completed within July and 1st fortnight of August as high rainfall exists from 27 to 33 SMW. The transplanted crop needs more water for puddling in addition to normal water requirement and the above period gets 40 mm rain at more than 50% probability.

In rainfed rice based cropping system, it is preferable to grow medium duration rice varieties, provide protective life saving irrigation from harvested rain water, harvest paddy at physiological maturity stage, strengthening of field bunds, check run off and seepage loss and block drainage channel. Prepositioning of inputs for *rabi* crops should be done to complete sowing in time.

Rabi

During 44 to 46 SMW (29th Oct. – 18th November) probability of getting 10 mm rainfall per week was more than 30 *per cent*. So, this period is most suitable for land preparation and sowing of *rabi* crops like wheat, green gram, black gram, horse gram, mustard, sesame, groundnut and vegetables like potato, onion, and chili can also be taken up. After 46 SMW (12th – 18th November) week farmers are advised for zero till sowing of pulse and oilseeds crops requiring less water. After 46 (12th – 18th November) week there is remote possibility of rain as the probability of rainfall is less than 30% for all the amounts i.e. for 10mm, 20mm and 40mm. Direct sowing of *rabi* crops just after harvest of *kharif* crops may also be tried to realize the advantage of residual moisture.

Reddy *et al*. (2008) [4] studied on Markov Chain Model Probability of Dry, Wet Weeks and Statistical Analysis of Weekly Rainfall for Agricultural Planning at Bangalore. In this study Markov Chain Model has been extensively used to study spell distribution The data on onset and withdrawal rainy season indicated that the monsoon starts effectively from 24th SMW (11 - 17th June) and remains active up to 45th SMW (5 - 11th November). During rainy season the probability of occurrence of wet week is more than 35% except during 25th - 27th SMW and 44th - 48th SMW. During rainy season the mean weekly rainfall is found to be more than 40 mm during 36th - 41st SMW and found to be less than 20 mm during 20th SMW, 25th - 27th SMW and 44th - 48th SMW. The results through analysis have been used for agricultural planning at Bangalore region.

Table 4: Initial and Conditional Probability at 20 mm

SMW	Initial Probability		Conditional Probability			
	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.09	0.91	0.00	0.00	0.91	0.09
2	0.09	0.91	0.50	0.50	0.95	0.05
3	0.00	1.00	0.00	1.00	1.00	0.00
4	0.04	0.96	0.00	0.00	0.96	0.04
5	0.09	0.91	0.00	1.00	0.91	0.09
6	0.00	1.00	0.00	1.00	1.00	0.00
7	0.09	0.91	0.00	0.00	0.91	0.09
8	0.00	1.00	0.00	1.00	1.00	0.00
9	0.04	0.96	0.00	0.00	0.96	0.04
10	0.04	0.96	0.00	1.00	0.95	0.05
11	0.04	0.96	0.00	1.00	0.95	0.05
12	0.09	0.91	0.00	1.00	0.91	0.09
13	0.09	0.91	0.50	0.50	0.95	0.05
14	0.17	0.83	0.50	0.50	0.86	0.14
15	0.09	0.91	0.25	0.75	0.95	0.05
16	0.17	0.83	0.50	0.50	0.86	0.14
17	0.22	0.78	0.50	0.50	0.84	0.16
18	0.30	0.70	0.20	0.80	0.67	0.33
19	0.30	0.70	0.29	0.71	0.69	0.31
20	0.39	0.61	0.43	0.57	0.63	0.38
21	0.43	0.57	0.33	0.67	0.50	0.50
22	0.35	0.65	0.60	0.40	0.85	0.15
23	0.57	0.43	0.50	0.50	0.40	0.60
24	0.83	0.17	0.77	0.23	0.10	0.90
25	0.74	0.26	0.79	0.21	0.50	0.50
26	0.91	0.09	0.94	0.06	0.17	0.83
27	0.87	0.13	0.86	0.14	0.00	1.00
28	0.83	0.17	0.85	0.15	0.33	0.67
29	1.00	0.00	1.00	0.00	0.00	1.00
30	0.91	0.09	0.91	0.09	0.00	0.00
31	1.00	0.00	1.00	0.00	0.00	1.00
32	0.91	0.09	0.91	0.09	0.00	0.00
33	0.91	0.09	0.90	0.10	0.00	1.00
34	0.91	0.09	0.90	0.10	0.00	1.00
35	0.78	0.22	0.76	0.24	0.00	1.00
36	0.78	0.22	0.72	0.28	0.00	1.00
37	0.78	0.22	0.78	0.22	0.20	0.80
38	0.78	0.22	0.83	0.17	0.40	0.60
39	0.57	0.43	0.50	0.50	0.20	0.80
40	0.65	0.35	0.62	0.38	0.30	0.70
41	0.39	0.61	0.40	0.60	0.63	0.38
42	0.48	0.52	0.56	0.44	0.57	0.43
43	0.30	0.70	0.27	0.73	0.67	0.33
44	0.09	0.91	0.00	1.00	0.88	0.13
45	0.13	0.87	0.50	0.50	0.90	0.10
46	0.26	0.74	0.33	0.67	0.75	0.25
47	0.00	1.00	0.00	1.00	1.00	0.00
48	0.00	1.00	0.00	0.00	1.00	0.00
49	0.04	0.96	0.00	0.00	0.96	0.04
50	0.04	0.96	0.00	1.00	0.95	0.05
51	0.00	1.00	0.00	1.00	1.00	0.00
52	0.00	1.00	0.00	0.00	1.00	0.00

Table 5: Probability of consecutive dry and wet spell at 20 mm

SMW	Consecutive dry probability			Consecutive wet probability		
	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0.87	0.87	0.83	0.05	0.00	0.00
2	0.91	0.87	0.79	0.00	0.00	0.00
3	0.96	0.87	0.87	0.00	0.00	0.00
4	0.87	0.87	0.79	0.00	0.00	0.00
5	0.91	0.83	0.83	0.00	0.00	0.00
6	0.91	0.91	0.87	0.00	0.00	0.00
7	0.91	0.87	0.83	0.00	0.00	0.00
8	0.96	0.91	0.87	0.00	0.00	0.00
9	0.91	0.87	0.79	0.00	0.00	0.00
10	0.91	0.83	0.79	0.00	0.00	0.00
11	0.87	0.83	0.71	0.00	0.00	0.00
12	0.87	0.75	0.71	0.04	0.02	0.01
13	0.78	0.74	0.64	0.04	0.01	0.01
14	0.78	0.67	0.56	0.04	0.02	0.01
15	0.78	0.66	0.44	0.04	0.02	0.00
16	0.70	0.46	0.32	0.09	0.02	0.01
17	0.52	0.36	0.22	0.04	0.01	0.01
18	0.48	0.30	0.15	0.09	0.04	0.01
19	0.43	0.22	0.18	0.13	0.04	0.03
20	0.30	0.26	0.10	0.13	0.08	0.04
21	0.48	0.19	0.02	0.26	0.13	0.10
22	0.26	0.03	0.01	0.17	0.13	0.11
23	0.04	0.02	0.00	0.43	0.34	0.32
24	0.09	0.01	0.00	0.65	0.61	0.53
25	0.04	0.00	0.00	0.70	0.60	0.51
26	0.00	0.00	0.00	0.78	0.67	0.67
27	0.04	0.00	0.00	0.74	0.74	0.67
28	0.00	0.00	0.00	0.83	0.75	0.75
29	0.00	0.00	0.00	0.91	0.91	0.83
30	0.00	0.00	0.00	0.91	0.83	0.75
31	0.00	0.00	0.00	0.91	0.83	0.75
32	0.00	0.00	0.00	0.83	0.75	0.57
33	0.00	0.00	0.00	0.83	0.63	0.45
34	0.00	0.00	0.00	0.70	0.50	0.39
35	0.00	0.00	0.00	0.57	0.44	0.37
36	0.04	0.02	0.00	0.61	0.51	0.25
37	0.09	0.02	0.01	0.65	0.33	0.20
38	0.04	0.01	0.01	0.39	0.24	0.10
39	0.13	0.08	0.05	0.35	0.14	0.08
40	0.22	0.12	0.08	0.26	0.14	0.04
41	0.35	0.23	0.20	0.22	0.06	0.00
42	0.35	0.30	0.28	0.13	0.00	0.00
43	0.61	0.55	0.41	0.00	0.00	0.00
44	0.83	0.62	0.62	0.04	0.01	0.00
45	0.65	0.65	0.65	0.04	0.00	0.00
46	0.74	0.74	0.71	0.00	0.00	0.00
47	1.00	0.96	0.91	0.00	0.00	0.00
48	0.96	0.91	0.91	0.00	0.00	0.00
49	0.91	0.91	0.91	0.00	0.00	0.00
50	0.96	0.96	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00

Crop management and planning strategies for the district

Under the ideal situation, medium to long duration rice varieties those are transplanted by the end of June will have its flowering period during the middle of September to early October. Flowering is a critical phase with respect to water requirement, as shortage of water during this time will affect subsequent grain filling and hence yield. Therefore farmers, especially those growing rice crops in need to arrange supplemental irrigation through tube wells, dug wells and harvested rain water. The rice crop is totally dependent on rainfall for water requirement. So, it is advisable to take up early and medium duration varieties, which will complete major reproductive stage by September. In lowlands a successful rainfed crop is possible with medium to long duration varieties with timely planting by 26 SMW or by direct sowing by 1st week of June before onset of monsoon. Measures like storage of runoff water in the fields, increasing bund height to 25-30 cm needs to be adopted for a successful rainfed crop.

Even under irrigated condition, transplanting by 26 SMW is crucial to make use of all rainwater and harvest a good crop of rice and a subsequent successful *rabi* crop. Under late planting situation in farmer's field, the phenophases like maximum tillering and panicle development comes during the

month of September. Since panicle development decides the number of grains in the panicle and tillering decides the number of panicles and hence capacity for higher yield, the availability of water during these periods is critical. Hence, it is important to ensure availability of irrigation water during the period. Scientific water management practices like irrigation at 3 days after disappearance of earlier ponded water instead of maintaining standing water continuously in the field can save up to 50% of irrigation water and make it available to irrigate more area. Increasing the bund height in the field up to 30 cm can also retain more rainwater in the field and increase the moisture content of the soil.

Balanced fertilizer application i.e., application of phosphorus and potash along with nitrogen (urea) can give the crop a certain extent of drought tolerance. By ensuring the release of irrigation water during the critical phases the crop failure and yield reduction can be avoided. Similarly, traditional water harvesting structures like ponds and tanks should be rejuvenated to enhance storage of runoff water and increase groundwater recharge.

As variability of rainfall is much more in post monsoon and winter months, sowing of *Rabi* crops can be suitably adjusted as per medium range weather forecasting and availability of soil moisture in the fields.

Conclusion

Monsoon starts effectively from 24 SMW (12 June to 15th June) in Bhadrak district and remain active up to 41 SMW (9th October to 13th October). Therefore, we expected good monsoon shower for about 17 weeks (24 to 41 SMW) in the region. So medium and late duration paddy (120-145 days) should be grown to avoid moisture stress during late reproductive stages. The long duration paddy varieties must be avoided as it may cause a heavy risk during drought or dry spell. However supplementary irrigation and moisture conservation need to be available if the crop is of long duration. The rainfall before 24 SMW should be utilized for land preparation and after 41 SMW the residual moisture should be utilized for pulses (green gram, black gram), oilseeds (Ground nut, Toria, Sesame) and various vegetables. Farmers should go for zero tillage practice for efficient use of soil moisture and save time for land preparation.

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