IWMI-TATA WATER POLICY RESEARCH PROGRAM

ANNUAL PARTNERS' MEET 2002

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Water Policy Program

Groundwater Development to Enhance Surface and Rain Water Utilization and Agricultural Productivity in Southern Bihar

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GROUNDWATER DEVELOPMENT TO ENHANCE SURFACE AND RAIN WATER UTILIZATION AND AGRICULTURAL PRODUCTIVITY IN SOUTHERN BIHAR

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Contents

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Abstract

A major chunk of economic progress of India continues to be through development in agriculture. This is the case with Bihar too where in low productivity has been one of the prime factors causing impoverishment. A case has been made in this paper towards eradicating poverty by enhancing productivity and intensifying farming, and by generating more employment in agriculture and other rural based production activities.

Introduction

The agricultural sector in India in general, and Bihar in particular, continues to occupy the center-stage in the overall economic progress and development. The role of agriculture inclusive of animal husbandry, dairy, and fisheries in generating broad based economic growth is evident from the fact that the sector has been contributing nearly 29 per cent of the GDP, and giving employment to about 66% of the population in the country. The percentage of population employed in agricultural production system in (undivided) Bihar is estimated to be 87%, which is more than the national average. The state of the erstwhile undivided Bihar as per 1998-99 agricultural statistics, possesses about 7.1% of the total cultivated area of the country, but produces about 6.4% of the total food grains. Rice and wheat are the major crops of Kharif and Rabi seasons occupying 5.07 million ha (mha) and 2.13 mha area respectively. The average yields of rice-wheat cropping system are 1.30 -1.99 t/ha as against the experimental yields of 7.21 - 3.96 t/ha, obtained in experimental plots at Sabour (Bihar). Although the state is rich in soil and water resources, the existing gap in experimental and average yields of rice-wheat-cropping system is computed as 5.9 - 2.04 t/ha. Thus, there is a considerable scope to increase the productivity of rice and wheat in Bihar.

Low productivity has been one of the prime factors causing impoverishment in Bihar. Poverty could be tackled by enhancing productivity and intensifying farming, and by generating more employment in agriculture and other rural based production activities. Hence, the goal of the agricultural production system is to maximize income of land owning and landless rural populace, thereby improve their standard of living. In the process, however, care should be taken to preserve the health of land, water and other natural resources, so that the agricultural production system remains sustainable and ever productive.

System's Approach to Enhance Rice-Wheat Productivity

Identification of Rice Production Constraints

A team of scientists from the ICAR Research Complex for Eastern Region (earlier Directorate of Water Management Research), Patna recognized the critical production constraint to rice-wheat production system as delay in seedling raising and transplanting of rice, and late sowing of wheat due to non-availability of canal water in time and its inequitable distribution, inadequate number of shallow tube-wells, ineffective use of rain-water, and lack of conjunctive use of different irrigation waters. It is corroborated from the fact that out of 200 farmers surveyed during 1998 only

28.5% had completed transplanting up to 21st July and remaining 71.5% up to 25th August. The aforementioned constraints have inhibited the realization of production potential in the plains of central Bihar. In order to identify other constraints, group meetings of several farmers were organized between March to June 1998 in the commands of RP Channel-5 and Majhouli distributaries that comprised 20 and 29 villages covering 3022 ha and 4311 ha area, respectively. The two distributaries are an integral part of Sone Canal System and irrigate areas of Naubatpur and Vikram blocks of Patna district. The critical analysis of the interactive meetings revealed other production constraints as: (i) cultivation of inappropriate and untested rice and wheat cultivars and use of poor quality seeds; (ii) imbalance and limited application of fertilizers, (iii) inadequate awareness about plant protection measures; (iv) non-availability of seed drill and other farm equipment; and (v) lack of proper technical guidance and support from the developmental agencies.

Soil Water Regime and Drought Spells in Rice Fields during 1998

For quantitative assessment of water regime in rice fields and irrigation schedule practiced by the farmers of the RP Channel 5 command, a study was conducted in 141 rice fields of the two villages, Rampur and Alipur, during the Kharif season of 1998. Depth of submergence in rice fields was measured with the help of a meter scale by placing it on a single brick platform created in the cropped fields. Occurrence of rainfall was also recorded on the observation sheet. Under All India Coordinated Research Project (AICRP) on Water Management (Singh et al., 1999) it has been observed that disappearance of submergence in the rice fields continuously for *three* days does not adversely affect the crop yield. Thus, a non-submergence period (days) beyond three days has been considered as a drought spell detrimental to the rice crop; hence, all those days in excess of three days in a spell were taken as critical water deficit days. During growth period of rice crop after transplanting, sum of all the critical water deficit days in each field was calculated. In order to have a dimensionless period of water deficiency, a Critical Water Deficit Index (CWDI) in percent has been defined as bellow.

$$\text{CWDI (\%)} = \frac{\sum_{r=1}^{r=p} \text{Critical Water Deficit Days in } r^{th} \text{ dry spell}}{\text{Crop Growth Period in days}} \times 100$$

in which, p is the number of critical dry spells in rice fields during crop growth period, and r is an index. The crop growth period for MTU 7029 has been taken as 120 days. The critical water deficit index (in percent) gives a numerical measure about the percent of crop growth period that experiences water deficiency. In the present study, the crop growth period has been considered as the period from the day of transplanting to crop maturity. In the absence of precise moisture measurement in the farmers' fields, this parameter is taken as a measure of the soil water deficiency in rice fields. The CWDI distribution in 67 rice fields of village Rampur is given in Table 1.

Table 1. Distribution of crop water deficit index in village Rampur during Kharif 1998

CWDI Class interval, percent	**No.of rice fields in Rampur**	**Relative frequency, percent**
I	II	III
0-5	0	0
5-10	2	2.99
10-15	2	2.99
15-20	6	8.96
20-25	9	13.43
25-30	7	10.45
30-35	11	16.41
35-40	10	14.92
40-45	9	13.43
45-50	7	10.45
50-55	4	5.97

A perusal of Table 1 reveals the following:

(i) 6% fields have CWDI up to 55, therefore, 6% fields have experienced 66 critical water deficit days.

(ii) Maximum number of fields (31.33%) lay in the CWDI range of 30-40%, i.e. the rice fields suffered 36 to 48 critical water deficit days.

(iii) About 24% rice fields have CWDI values between 40 and 50%; hence these fields suffered critical water deficiency for 48 to 60 days.

It may be remembered that the CWDI is only a measure of non-submergence period in rice fields; it does not give complete information about the soil moisture status of the root zone.

The distribution of CWDI in 74 rice fields of village Alipur is reported in Table 2.

Table 2. Distribution of crop water deficit index in village Alipur during Kharif 1998

CWDI Class Interval, percent	No. of rice fields in Alipur	Relative frequency, percent
I	II	III
0-5	1	1.35
5-10	4	5.4
10-15	19	25.68
15-20	23	31.08
20-25	17	22.97
25-30	8	10.81
30-35	1	1.35
35-40	1	1.35

The scrutiny of Table 2 reveals the following:

I. About 26% and 31% of the rice fields are in the CWDI range of 10-15% and15-20%, therefore these fields have suffered respectively, a critical water deficiency for 12-18 days and 18-24 days.
II. About 23% of the farmers' fields have experienced critical water deficiency for 24-30 days.
III. Only 13.5% of the rice fields have suffered critical water deficiency for 30-48days.

In order to study the adequacy of soil water regime in rice fields, the lengths of critical dry spells were computed for each field whose moisture regimes were observed throughout the crop-growth period of Kharif 1998. The distribution of critical dry spell lengths in rice fields in two villages, Alipur and Rampur, is reported in Tables 3 and 4, respectively. The plots of these distributions are depicted in Figures 3 and 4 for easy visualization of magnitude. A perusal of Table 3 and Figure 1 reveals rice fields in village Alipur suffering critical dry spells of as low as one day to as high as 32 days. Around 60% of the fields have experienced a critical dry spell of one day, and 51% two days. Fields suffering critical water deficiency of three, four, five, six, seven, and eight days constituted 38, 38, 30, 31, 32, and 23 percents, respectively. As evident from Table 4 and Figure 2, the rice fields in village Rampur experienced critical water deficiency of one day to 29 days. About 58 and 55 percents rice fields underwent critical water deficiency of one and two days, respectively. Rice fields experiencing critical dry spell lengths of three, four, five, six, seven, and eight days comprised of 46, 45, 40, 43, 21, and 22 percents, respectively. The rainfall occurring during these dry spells was not enough to cause soil submergence; however, during many dry spells it was sufficient to meet the potential evapotranspiration demand. This study helped us in educating the farmers to irrigate rice fields to overcome long dry spells.

Table 3. Distribution of critical dry spell lengths in 74 rice fields in village Alipur during Kharif 1998.

Length of critical dry spell, days	Rice fields, percent	Length of critical dry spell, days	Rice fields, percent
1	59.5	17	8.1
2	51.4	18	1.4
3	37.8	19	2.7
4	37.8	20	1.4
5	29.7	21	1.4
6	31.1	22	2.7
7	32.4	23	1.4
8	23.0	24	1.4
9	12.2	25	1.4
10	12.2	26	1.4
11	14.9	27	0.0
12	21.6	28	1.4
13	12.2	29	0.0
14	8.1	30	1.4
15	9.5	31	1.4
16	6.8	32	1.4

Fig.1: Disrtribution of critical dry spell length in 74 rice fields during Kharif-99 in village Alipur

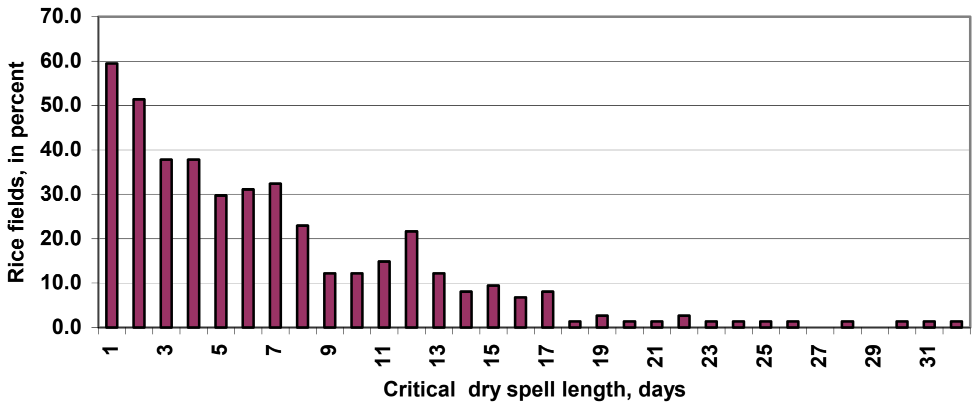
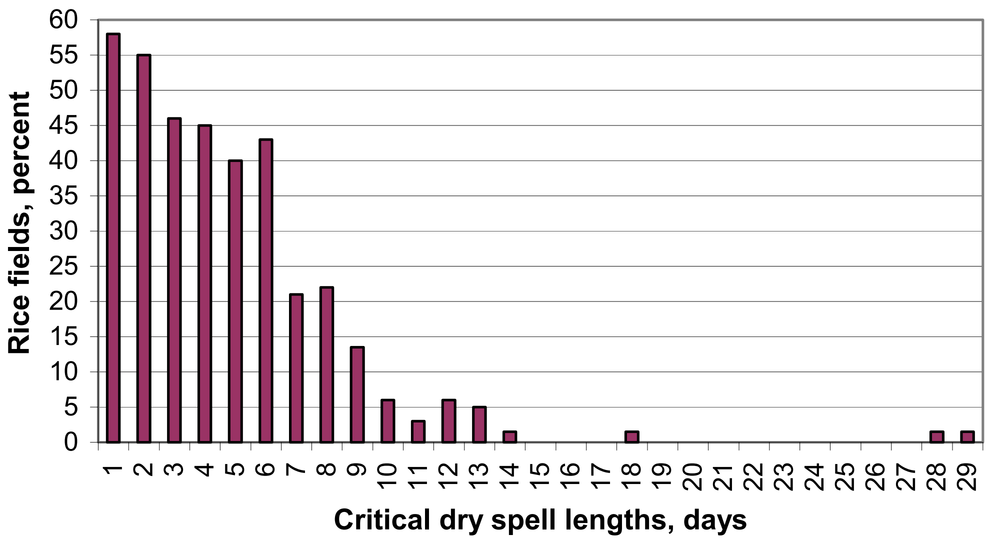


Table 4. Distribution of critical dry spell lengths in 67 rice fields in village Rampur during Kharif 1998

Length of critical dry spells (days)	Rice fields, in percent	Length of critical dry spells (days)	Rice fields in percent
1	58	15	0
2	55	16	0
3	46	17	0
4	45	18	1.5
5	40	19	0
6	43	20	0
7	21	21	0
8	22	22	0
9	13.5	23	0
10	6	24	0
11	3	25	0
12	6	26	0
13	5	27	0
14	1.5	28	1.5
		29	1.5

Fig.2: Distribution of critical dry spell lengths in the rice fields in village Rampur



Alternative Interventions to Enhance Rice Production

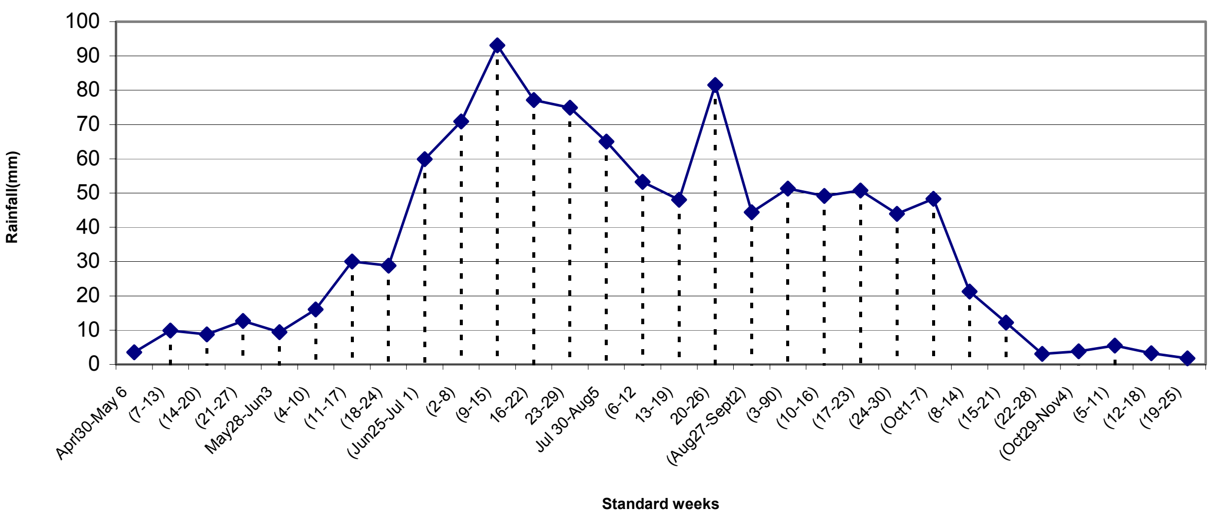
The monsoon at Patna breaks during the second week (11th) of June. The mean weekly rainfall of forty years (1960 to 1999) of Patna is given in Table 5 (Das and Subash, 2001, Personal communication) and its plot in Figure 3. From the figure it is amply clear that annual rainfall is about 1142.5mm and bulk of the rain occurs during the months of June, July, August, September, and October. The analysis of rainfall data (Singh et al.1996) of Patna has revealed that on an average (i) the rainfall during the period 18th June to 5th July for 18 days, and during 24th October to 10th November for 18 days is greater than 50 percent of potential evaporation but less than potential evaporation, and (ii) the rainfall for 110 days during the period 6th July to 23rd October is greater than potential evaporation. The authors have termed the aforesaid periods of moisture availability as Moist 1 (18th June – 5th July), Humid (6th July –23rd October), and Moist 2 (24th October- 10th November) regimes. The moisture regimes for other meteorological stations of eastern India are reported in Table 6.

The moisture regimes given in Table 6 are quite useful in crop planning. For example, during a normal year at Patna, the rainfall will meet the rice crop water demand throughout the humid period of 6th July to 23rd October. However, irrigation will be needed to mitigate the effect of the drought spell and to pond water in rice fields for weed control.

Table 5. Normal weekly rainfall at Patna during Forty years (1960-1999)

Std.Week	Month	Date	Rainfall (mm)	Std. Week	Month	Date	Rainfall (mm)
1	Jan.	1-7	2.1	26	July	25-1	59.9
2		8-14	1.4	27		2-8	70.9
3		15-21	3.3	28		9-15	93.1
4		22-28	2.8	29		16-22	77.1
				30		23-29	74.9
5	Feb.	29-4	2.7	31	August	30-5	65.0
6		5-11	2.9	32		6-12	53.3
7		12-18	5.1	33		13-19	48.0
8		19-25	3.9	34		20-26	81.5
9	March	26-4	2.5	35	September	27-2	44.4
10		5-11	2.4	36		3-9	51.3
11		12-18	2.6	37		10-16	49.2
12		19-25	3.2	38		17-23	50.7
				39		24-30	43.9
13	April	26-1	1.3	40	October	1-7	48.3
14		2-8	0.7	41		8-14	21.3
15		9-15	1.3	42		15-21	12.2
16		16-22	3.3	43		22-28	3.1
17		23-29	6.1				
18	May	30-6	3.5	44	November	29-4	3.8
19		7-13	9.9	45		5-11	5.5
20		14-20	8.8	46		12-18	3.3
21		21-27	12.7	47		19-25	1.8
22	June	28-3	9.4	48	December	26-2	2.7
23		4-10	16.0	49		3-9	1.5
24		11-17	30.0	50		10-16	2.0
25		18-24	28.8	51		17-23	2.1
				52		24-31	5.0

Figure 3. Forty years (1960-99) normal weekly rainfall at Patna



Annual rainfall = 1142.5 mm

Table 6. Water availability periods at different stations in eastern India

S.No.	State	Station	Moist I	Humid	Moist II
1.	Madhya Pradesh	Raipur	16 Jun – 29 Jun (14)	30 Jun – 24 Oct (117)	25 Oct. – 11 Nov (18)
2.	Madhya Pradesh	Champa	16 Jun – 29 Jun (14)	30 Jun – 25 Oct (118)	26 Oct. – 6 Nov (12)
3.	Madhya Pradesh	Ambikapur	18 Jun – 29 Jun (12)	19 Jun – 21 Oct (113)	22 Oct – 7 Nov (12)
4.	Madhya Pradesh	Umaria	18 Jun – 29 Jun (12)	30 Jun – 21 Oct (114)	22 Oct – 7 Nov (17)
5.	Madhya Pradesh	Jagadalpur	31 May – 15 Jun (12)	16 Jun – 9 Nov (147)	10 Nov – 27 Nov (18)
6.	Madhya Pradesh	Kanker	9 Jun – 24 Jun (16)	25 Jun – 4 Nov (133)	5 Nov – 21 Nov (17)
7.	Madhya Pradesh	Rai garh	13 Jun – 27 Jun (15)	28 Jun – 30 Oct (125)	31 Oct – 12 Nov (13)
8.	Madhya Pradesh	Pendra	12 Jun – 24 Jun (13)	25 Jun – 31 Oct (117)	1 Nov – 18 Nov (18)
9	Madhya Pradesh	Jabalpur	16 Jun – 25 Jun (10)	26 Jun – 22 Oct (119)	23 Oct – 9 Nov (18)
10.	Madhya Pradesh	Satna	21 Jun – 4 Jul (14)	5 Jul – 15 Oct (103	16 Oct – 5 Nov (21)
11.	Uttar Pradesh	Lucknow	30 Jun – 13 Jul (14)	14 Jul – 13 Oct (92)	14 Oct – 31 Oct (18)
12.	Uttar Pradesh	Allahabad	26 Jun – 13 Jul (19)	14 Jul – 15 Oct. (94)	16 Oct – 3 Nov (19)
13.	Uttar Pradesh	Fatehpur	30 Jun – 12 Jul (12)	13 Jul – 8 Oct (88)	9 Oct – 29 Nov (21)
14.	Uttar Pradesh	Gorakhpur	11 Jun – 25 Jun (15)	26 Jun – 26 Oct (123)	27 Oct – 14 Nov (19)
15.	Uttar Pradesh	Kanpur	9 Jul – 24 Jul (16)	25 Jul – 13 Oct (81)	14 Oct – 31 ct (18)
16.	Uttar Pradesh	Gonda	16 Jun – 29 Jun (14)	30 Jun – 26 Oct (119)	27 Oct – 12 Nov (17)
17.	Uttar Pradesh	Bahraich	18 Jun – 3 Jul (16)	4 Jul – 23 Oct (112)	24 Oct – 14 Nov (22)
18.	Bihar	Patna	18 Jun – 5 Jul (18)	6 Jul – 23 Oct (110)	24 Oct – 10 Nov (18)
19.	Bihar	Ranchi	5 Jun – 19 Jun (15)	20 Jun – 5 Nov (139)	6 Nov – 25 Nov (20)
20.	Bihar	Bhagalpur	7 Jun – 22 Jun (16)	23 Jun – 27 Oct (128)	28 Oct – 14 Nov (18)
21	Bihar	Darbhanga	6 Jun – 22 Jun (16)	22 Jun – 27 Oct (129)	28 Oct – 14 Nov (18)
22.	Bihar	Hazaribagh	12 Jun – 21 Jun (16)	28 Jun – 29 Oct (124	30 Oct – 16 Nov (18)
23	Bihar	Jamshedpur	7 Jun – 20 Jun (14)	21 Jun – 26 Oct (128)	27 Oct – 17 Nov (22)

24	Bihar	Gaya	25 Jun – 10 Jul (17)	11 Jul – 13 Oct (95)	14 Oct – 4 Nov (22)
25.	Bihar	Daltonganj	18 Jun – 29 Jun (12)	30 Jun – 24 Oct (117)	25 Oct – 11 Nov (17)
26.	Bihar	Sabour	7 Jun – 22 Jun (16)	23 Jun – 27 Oct (128)	28 Oct – 15 Nov (18)
27.	Orissa	Balasore	19 May – 11 Jun (24)	12 Jun – 23 Nov (165)	24 Nov – 10 Dec (17)
28.	Orissa	Gopalpur	3 Jun – 25 Jun (23)	26 Jun – 28 Nov (156)	29 Nov – 16 Dec (18)
29.	Orissa	Titlagarh	9 Jun – 21 Jun (13)	22 Jun – 3 Nov (135)	4 Nov – 18 Dec (15)
30	Orissa	Sambalpur	8 Jun – 19 Jun (12)	20 Jun – 28 Oct (131)	29 Oct – 14 Nov (17)
31	Orissa	Cuttack	31 May – 17 Jun (18)	18 Jun – 17 Nov (153)	18 Nov – 5 Dec (18)
32.	Orissa	Berahampur	17 May – 9 Jun (24)	10 Jun – 9 Nov (153)	10 Nov – 26 Nov (17)
33.	West Bengal	Calcutta	15 May – 7 Jun (24)	8 Jun – 11 Nov (157	12 Nov – 30 Nov (19)
34.	West Bengal	Purulia	9 Jun – 24 Jun (16)	25 Jun – 1 Nov (130)	2 Nov – 16 Nov (15)
35.	West Bengal	Baghdogra	28 Apr – 14 May (17)	15 May – 17 Nov (187)	18 Nov – 30 Nov (13)
36.	West Bengal	Burdwan	20 May – 16 Jun (28)	17 Jun – 2 Nov (139)	3 Nov – 24 Nov (22)
37.	West Bengal	Midnapur	20 May – 11 Jun (23)	12 Jun – 12 Nov (154)	13 Nov – 3 Dec (21)
38.	Assam	Silchar	19 Feb – 23 Mar (33)	24 Mar – 26 Nov (248)	27 Nov – 13 Dec (17)
39.	Assam	Tezpur	24 Mar – 21 Apr (29)	22 Apr – 12 Nov (205)	13 Nov – 4 Dec (22)
40	Assam	Dibrugarh	2 Feb – 27 Feb (25)	28 Feb – 24 Nov (270)	25 Nov – 15 Dec (19)
41.	Assam	Dhubri	2 Apr – 22 Apr (21)	23 Apr – 16 Nov (208)	17 Nov – 30 Nov (11)
42	Assam	Gauhati	28 Mar – 25 Apr (28)	26 Apr – 2 Nov (191)	3 Nov – 23 Nov (21)
43.	Meghalaya	Cherapunji	14 Feb – 6 Mar (21)	7 Mar – 9 Dec (278)	10 Dec – 18 Dec (9)
44.	Mizoram	Aizwal	22 Mar – 18 Apr (28)	19 Apr – 28 Nov (224)	29 Nov – 15 Dec (17)

Values in the parenthesis are number of days.

Traditionally rice was cultivated in high rainfall areas where water was abundantly available. Although the farmers did not develop water resources for regular irrigation of the rice crop, they did utilize accumulated run off water in ponds, lakes, rivulets, or any other local depressions for irrigating the rice fields during prolonged dry spells either for field preparation or to protect the crop from withering. The income associated with the adoption of high yielding rice cultivars encouraged the farmers to cultivate rice in areas having assured irrigation supply. Thus, with the development of water resources for irrigation, rice cultivation spread to medium to low rainfall areas as well. However high yields of rice could be obtained only by eliminating moisture stress through assured irrigation and better utilization of rainwater.

In order to minimize irrigation and enhance effective utilization of rainwater to the cultivation of long duration rice varieties of 155 days, the rice seedling should be ready for transplant immediately after the onset of monsoon. Considering that a 155 - day rice variety would require a 30- day old seedling, the optimum time for seeding rice nursery falls around 26th May. Such a nursery could be transplanted around 25th June. It would be ready for harvest around 28th October, thereby making the land available for Rabi cultivation. A perusal of the rainfall pattern indicates availability of rainwater till 10th November. If the soil moisture condition is favourable, a farmer may perform tillage operations to prepare his land for Rabi crops. Under excessive soil moisture condition, the farmer may keep his land fallow for solar drying till such time as the condition becomes favourable for land preparation.

The farmers of the commands used to raise seedlings from the third week of June to the second week of July and transplant from the third week of July to the third week of August. Consequently, the harvesting took place from the last week of November to the 2nd week of December. The prevailing practice falls short of making full use of rainfall in rice production. The late paddy harvesting causes a considerable delay in wheat sowing, which very often is sown until the first week of January while its optimum time is from 15th November to 30th November. As wheat is highly thermo-sensitive, late sowing considerably hampers its yields. Late harvesting also delays sowing of lentil, Bengal gram and other Rabi crops. The optimum time of sowing lentil in central Bihar is from 15th October to 15th November. Late sowing exposes the crop to low temperature and frost at the sensitive growth stage of flowering

Selection of Best Interventions

After identifying the crop production constraints, the following interventions were adopted to increase crop productivity in the canal commands using systems approach:

(i) Educating farmers about advancing the dates of nursery raising and transplanting of rice, and sowing of wheat and other Rabi crops,
(ii) Training farmers about improved rice production technology including cultivars, seed rate, nursery raising, plant population at the time of transplanting, field preparation, use of balanced fertilizers, water, weed, and pest management,
(iii) Training farmers about improved wheat and other Rabi crop production technologies including cultivars, use of zero till seed drills, and nutrient, weed, water, and pest management,
(iv) Formation of water users' associations and training about water management,
(v) Training farmers about improved production of potatoes and other vegetables,
(vi) Training on papaya cultivation,
(vii) Demonstrations of improved rice, wheat, lentil, Bengal gram, potato, and papaya production technologies.

Final Plan for Implementation and Outcomes

Imparting Training to Farmers

Major emphasis during the implementation phase of the project was on enhancing technical skills of the farmers about various agricultural production technologies. Experts from DWMR and Centre for Environment, Agriculture, and Development organized 118 training camps, and Kisan Gosties (farmers' workshops) on different aspects of agricultural production system during 1998, 1999, 2000, and 2001. In these programmes, a total of 6447 farmers from the commands of seven distributaries of Sone Canal System and four villages of Barh area participated. Apart from this, exhibitions and farmers' fairs were also organized. Experts from DWMR, IARI, IPM, and CPRS, Patna have delivered lectures in the fields of their expertise.

Details of farmers' training camps are reported in Table 7. The improved production technologies advocated by the experts were demonstrated on a very small scale. In all the training camps, there was greater emphasis on participation by farmers using their own resources in increasing rice and wheat production. There was less emphasis on large-scale demonstrations usually practiced in other projects.

Table 7. Details of year wise farmers' training camps

Programme	**1998**		**1999**		**2000**		**2001**		**Total**	
Training Programme	No.	Partici-pants	No.	Partici-pants	No.	Partici-pants	No.	Partici-pants	No.	Partici-pants
(a) Improved rice Cultivation	4	158	8	409	9	416	14	488	35	1471
(b) Improved wheat Cultivation	-	-	4	112	8	349	-	-	12	461
(c) Improved Vegetable Cultivation	-	-	1	31			3	40	4	71
(d) Improved Lentil Cultivation	-	-	-	-	2	49	-	-	2	49
(e) Dairy management	-	-	3	74	-	-	-	-	3	74
(f) Participatory Irrigation management	-	-	5	160	-	-	-	-	5	160
(g) Formation of Self Help Group	-	-			1	20	2	43	3	63
(h) Pusa Bin	-	-			2	56			2	56
Kisan Gosthi			8	261	16	490	23	991	47	1742
Kisan Diwas	-	-			2	1200			2	1200
Exhibition	-	-	-	-	3	1100			3	1100
Total	**4**	**158**	**29**	**1047**	**43**	**3680**	**42**	**1562**	**118**	**6447**

Improved Rice Production Technology

On the basis of the constraints identified, a team of scientists from DWMR and many other eminent scientists supported by Center for Environment, Agriculture and Development, Post Box No.11321, New Delhi conducted several farmers' training camps in the canal command villages to emphasize on advancing the date of transplanting by 15-30 days by raising nursery from the last week of May till the first week of June using tube -well water, and transplanting it from the last week of June till the middle of July for maximum utilization of rain water. Such a practice would save about 2-3 irrigations usually required by the rice transplanted late during its last growth phase. Sowing of nursery during the last week of May 1999 required a maximum of three irrigations by tube well water prior to the availability of canal water.

The team also advised the farmers to use improved cultivars like Pusa 834 for short duration, and MTU 7029 and MTU 1001 for long duration cultivations. In order to grow healthy nursery for transplanting 0.4 ha (one acre) area, the farmers were advised to sow 10 kg of good quality rice seeds in 375 m^2 bed as against their normal practice of sowing 30 kg seed in 250 m^2 area. A balanced basal doze of 2 kg urea, 4 kg single supper phosphate, 0.5 kg muriate of potash, and 0.75 kg zinc sulphate was applied in 375 m^2 nursery bed. The farmers were told to apply 100 kg SSP, 16 kg MOP, and 8 kg zinc sulphate as basal dose in 0.4 ha area at the time of puddling.

The farmers were advised to transplant 2-3 seedlings per hill, and each seedling containing 2-3 tillers at a distance of 15cm x 20 cm for long duration varieties, and at a distance of 15 cm x 15 cm for short duration varieties. This amounts to 33 hills/m^2 for long duration varieties, and 44 hills/m^2 for short duration varieties. On their own, the farmers were transplanting 8-12 seedling per hill and were using only urea as fertilizer. The farmers were advised to apply 17 kg urea per acre after seven days of transplanting. The team also suggested three top dressings of rice fields by urea at the rate of 20 kg/acre at an interval of 20 days.

The farmers were also told to mix one liter of Machete (Butachlore 50% EC) in 15 kg of sand and broadcast in one-acre rice field between fourth to seventh days after transplanting, to control weed growth. In case of stem borer attack, a solution of democran @ 1ml / 3 lit or monochrotophos @ 1 ml/ lit was sprayed in the rice fields. In order to control gandhi bug, malathyan @ 12 kg/acre was dusted in the rice fields.

Groundwater as the Key Input to the Adoption of Improved Rice Production Technology

Seeding rice nursery during the last week of May till the first week of June requires development of ground water by installing shallow tube-wells as the canal water is not available in its tail reaches during this period. A survey conducted during 1999 revealed that110 farmers owned shallow tube-wells in the 3022 ha command of RP Channel-5, which works out to quite a low tube-well density of 3 / sq kma. Six demonstrations at five locations were carried out in the commands of RP Channel-5 and Majhauli distributaries during Kharif season of 1999 to test the recommended production package. Farmers of Sangrampur village raised a community nursery under a tube well command in about 1.5 acre area adopting a fully improved rice production package under technical guidance of scientists from DWMR and CEAD. Even though no demonstrations were laid during 2000, the monitoring on the demonstration sites continued during the Kharif 2000 as well. The effect of timely nursery raising using tub-well water and number of tube-well irrigations needed for rice nursery in 1999 and 2000 are given in Table 8. As evident from the Table, the farmers applied three irrigations during 1999, and 2-3 irrigations during 2000 from tube-well to raise the rice nursery. Table 8 also contains the date of nursery seeding by the six farmers under their traditional method of rice cultivation during Kharif 1998. Late nursery seeding and transplanting has yielded only 2.88 t/ha on the fields of the six farmers during 1998. The improved production technology resulted in bumper paddy yields of 6 to 7 t/ha (based on crop cutting experiment in 3m x 3m area) as against the traditional yields of 1.6 to 3 t/ha. The recommended practices were adopted by the farmers in 100 acres in different villages and harvested almost the same yields. As the farmers harvested unprecedented high yields, the improved rice production technology became an important issue for discussion among the farmers. Consequently, the farmers from the adjoining commands of five distributaries namely Kurkuri, Rewa, Narayanpur, Fatehpur, and Khajuri of Sone canal system approached us to adopt their villages. In a farmers' meeting (Kisan Ghosti) held on 8thApril, 2000 at village Bhelura Rampur 73 villages in the commands of the aforesaid five distributaries were adapted. Paliganj distributary commanding 12197 ha area in 56 villages has been adopted during Rabi 2000-2001. Directorate of Water Management Research with the support of Centre for Environment, Agriculture and Development has been operating in 178 villages in the commands of eight distributaries to enhance crop productivity. The DWMR is also helping the farmers of four villages to enhance the production of lentil and Bengal gram in Tal (low lands) areas in Barh region of district Patna. The number of villages constituting the command of each distributary is reported in Table 5. During the Kharif season of the year 2000 the full package of improved rice production technology has been adopted by the farmers of the aforesaid distributaries in an estimated area of 480 ha spread over 86 villages (Table 9). Partial adoption of the improved rice production technology package has spread over 8994 ha area in 102 villages (Table 9).

Table 8. Effect of raising nursery timely using tube-well water on paddy yield on demonstration plots

Standard Week	Area Transplanted, ha	Area Transplanted Percent
27 (02-08 July)	69.0	6.4
28 (09-15 July)	185.1	17.2
29 (16-22 July)	306.2	28.4
30 (23-29 July)	290.1	26.9
31 (30 July-05 Aug)	132.3	12.3
32 (06-12 Aug)	90.0	8.4
33 (13-19 Aug)	4.0	0.4
34 (20-26 Aug)	1.0	0.1
35 (27Aug-02Sep)	1.0	0.1

Table 9: Adoption of improved rice and wheat production technologies in the distributary commands.

S.No.	Farmer Name	Village	1998		1999				2000			
			Date of Nursery Seeding & Variety	Yield (t/ha)	Date of Nursery Seeding using Tubewell Water & Variety	No. of Irrigation from Tubewell in Nursery Raising	Date of Transplanting	Yield (t/ha)	Date of Nursery Seeding & Variety	No. of Irrigation from Tubewell in Nursery Raising	Date of Transplanting	Yield (t/ha)
1	Arun Kumar	Sangrampur	13.7.98 Sita	3	3.6.99 MTU 7029	3	8.7.99	6.5	1.6.2000 MTU 7029	2	14.7.2000	6.5
2	Baikunth Sharma	Sangrampur	13.7.98 Sita	2.5	3.6.99 MTU 7029	3	8.7.99	6.7	18.6.2000 MTU 1001	2	18.7.2000	5.7
3	Punanjaya Sharma	Sangrampur	29.6.98 Saryug	2.9	5.6.99 Pusa 834	3	13.7.99	6.3	14.6.2000 BPT 5656	3	20.7.2000	5.7
4	Ram Bhuwan Sharma	Sangrampur	13.7.98 Local	2.7	3.6.99 MTU 7029	3	8.7.99	7	10.6.2000 MTU 1001	2	3.7.2000	6.3
5	Sanjay Kumar	Sikariya	5.7.98 Local	2.5	3.6.99 Pusa 834	3	8.7.99	6.1	19.6.2000 MTU 7029	2	17.7.2000	5.7
6	Ramanand Sharma	Bhelura Rampur	22.6.98 Sita	3.5	3.6.99 Pusa 834	3	8.7.99	6.4	5.6.2000 MTU 7029	2	7.7.2000	7.4

Progress in adoption of improved rice production technology during two Kharif seasons of 1999 and 2000 was spectacular as the entire work was undertaken with emphasis on farmers' participation without much dependence on demonstration The scientists of the Directorate of Water Management Research conducted surveys in 17 villages in the commands of seven distributaries around the time of transplanting of rice by the farmers who have adopted the improved rice production technology. The sample area comprised of 370 ha. Distribution of the area transplanted in different standard weeks during kharif 2000 is given in Table 10.

Table 10. Rice area transplanted in different standard weeks during Kharif 2000 by the farmers adopting improved technology

Standard Week	Area Transplanted, ha	Area Transplanted Percent
26 (25Jun-01 July)	6.0	1.6
27 (02-08 July)	73.8	19.9
28 (09-15 July)	96.0	25.9
29 (16-22 July)	132.2	35.7
30 (23-29 July)	62.0	16.8

As revealed from Table 10, the bulk of the transplanting to the tune of about 62% took place during 9-22 July corresponding to 28th and 29th weeks. Only about 20% area was transplanted on 2nd to 8th July (27th week).

Table 11. Rice area, transplanted in different standard weeks during Kharif 2000 in the command of RP Channel-5 by farmers practicing traditional cultivation practices.

Name of the distributary	No. of villages in the command	Cultu-rable command area, ha	Adoption of improved crop production technology in villages and area, ha							
			Rice technology in Kharif-99		Wheat technology in Rabi 99-2000		Rice technology in Kharif-2000			
			No. of villa-ges	Area, ha	Villages	Area, ha	No. of villages	Area, ha	Partial adoption seen over	
									No. of villages	Area, ha
RP CHANNEL-5	20	2203	09	24	09	30	20	204	20	2203
Majhouli	29	2516	06	16	08	25	25	146	29	2516
Kurkuri	20	2962	-	-	-	-	13	60	15	1500
Khujuri	8	1485	-	-	-	-	05	15	08	950
Narayanpur	3	-	-	-	-	-	03	10	03	25
Rewa	19	7922	-	-	-	-	10	15	12	800
Fatehpur	23	10741	-	-	-	-	10	30	15	1000
Paliganj	56	12197	-	-	-	-	Proposed			Rabi-2001
Barh	04									
Total	182	40026	15	40	17	55	86	480	102	8994

Sample size: Area - 1078.7 ha; No. of villages - 9 villages; No. of farmers - 776

Table 11 gives the time distribution of 1078.7 ha transplanted area in the command of RP Channel-5 during kharif 2000. The sample has been collected from 9 villages in the fields of the farmers who have not adopted the improved rice production technology.

Distribution of transplanted area in the commands of Majhauli distributary during kharif 2000 is given in Table 12. As Majhauli distributary is in the lower reach in comparison to RP Channel-5, it could suffer more deprivation of water than RP Channel-5.

Table 12. Rice area transplanted in different standard weeks during Kharif 2000 in the command of Majhouli distributary, District Patna

Standard week	Area transplanted (ha)	Area transplanted Percent
26 (25 Jun – 01 July)	10.1	0.99
27 (02-08 July)	52.8	5.2
28 (9-15 July)	142.3	14.0
29 (16-22 July)	251.0	44.89
30 (23-29 July)	233.8	23.0
31 (30 July – 05 August)	177.4	17.4
32 (06-12 August)	72.0	7.1
33 (13-19 August)	51.0	5.0
34 (20-26 August)	25.3	2.5
35 (27 August – 02 Sept.)	0.8	0.1

Sample size: Area: 1016.5 ha; No. of villages:16 villages; No. of farmers: 1200

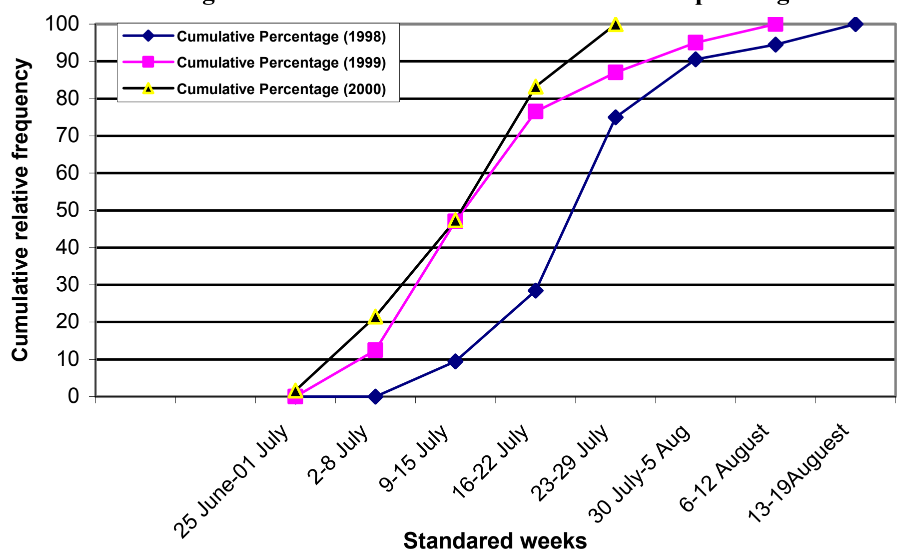
A perusal of Table 10, 11, and 12 reveals completion of rice transplanting in about 83%, 52%, and 65% area, respectively by 22nd July. Thus, the farmers practicing improved rice production technology have transplanted 13 to 31% more area by 22nd July in comparison to the farmers practicing traditional methods of rice cultivation.

One of the key interventions of improved rice production technology is to educate the farmers about the advantages of early nursery raising and transplanting. Table 13 gives the percentage of farmers' fields transplanted in different weeks during kharif 1998, 1999, and 2000. The sample has been drawn from 370 ha area in 17 villages. The cumulative percentage of farmers' fields transplanted during different weeks is depicted in Fig.2. A comparison of the cumulative curves of 1998, 1999, and 2000 gives the effect of intervention in advancing the date of nursery raising and transplanting. It is clear from Table 13 and Fig.4 that till 22nd July, only 28.5% of the farmers had completed their transplanting in 1998 whereas the percentage increased to 76.5% and 83.1% during kharif 1999 and 2000 respectively.

Table 13. Trend of transition of rice transplantation before intervention (1998) and after intervention (1999 & 2000)

S. No.	Standard weeks of transplanting	Percentage of farmers' field trans-planted (1998)	Cumula-tive Percentage (1998)	Percentage of farmers field trans-planted (1999)	Cumula-tive Percentage (1999)	Percentage of farmers' field transplanted (2000)	Cumulative Percentage (2000)
1.	26 – 25 June – 1 July	0		0	0	1.6	1.6
2.	27 - 2-8 July	0	0	12.5	12.5	19.9	21.5
3.	28 - 9-15 July	9.5	9.5	34.5	47	25.9	47.4
4.	29 – 16-22 July	19	28.5	29.5	76.5	35.8	83.2
5.	30 – 23-29 July	46.5	75	10.5	87	16.8	100
6.	31 – 30 July – 5 August	15.5	90.5	8	95	0	
7.	32 - 6-12 August	4	94.5	5	100	0	0
8.	33 – 13-19 August	5.5	100	0	0	0	

Fig.4. Intervention effect on date of rice transplanting



Dependence of Rice Cultivation on Tube-well, Canal, and Rain Waters during 1999

Conjunctive use of tube well, canal, and rain waters is essential for timely seeding of rice nursery, transplanting, and creating favourable soil water regime in rice fields. In order to study the use of different sources of irrigation water in rice production, soil water regime in 38 fields in two villages of Rampur and Alipur was monitored daily during Kharif 1999 commencing from transplanting till crop maturity. As the two villages are located in the tail end of RP Channel-5 distributary, the farmers of these villages receive canal water only after it has satisfied the demands in the upper reaches of the distributary. The seeding of rice nursery in these two villages is primarily performed using tube well water. The depth of water in each field as well as the source of supply of water to the field was recorded daily using a measuring scale. Since rice is commonly cultivated under shallow submerged water regime, daily measurement of depth of submergence was taken to study the sufficiency or otherwise of water supply to rice crop. In the absence of sophisticated instrumentation in the field, only the depth of water was measured daily with the help of a meter scale by placing it on a single brick platform created in the rice field. Whenever there was a rainfall, its occurrence was recorded on the observation sheet. When a field was irrigated using canal or tube well waters, the same was also recorded on the observation sheet. The canal irrigation is usually field-to-field irrigation; but in tube-well irrigation water is conveyed to the field using a flexible plastic pipe. When no water was present in the field, the visual status of soil wetness was also recorded on the data sheet. Such fields were counted as dependent on rainwater. The data was analyzed for weekly dependence of rice crop on canal, tube well, and rain water supplies, which is reported in Table 14, and depicted in Fig.5. Weekly rainfall during the crop growth period of Kharif-99 is reported in Table 15. During the period 9th July to 4th November, rainfall has been zero only during two weeks, 22-28 October, and 29th October to 4th November. The rainfall in other weeks has helped the soil water regime becoming more favourable to rice crop.

As evident from Table14 and Figure 5, during early growth phase of the rice crop (9th July to 5th August) coinciding with the rain period, the farmers in these two villages were primarily dependent on tube well and rain waters to satisfy the water requirement of rice crop. During the period 6th August to 16th September, more than 50 per cent of the rice fields received canal water supplies, and the weekly rainfall ranged between 6.2mm to 79.0 mm; consequently, there was quite low dependency of rice fields on tube well water. The canal water availability during the period 1st October to 28th October was quite adequate as more than 90 per cent fields were irrigated with canal water; therefore, the dependence of rice fields on rain water and tube well water declined considerably. For two weeks during the latter half of September, there was less supply of canal water and hence fields were dependent either on tube well water or residual moisture and rainwater. It may be noted that during the entire crop growth period of 17 weeks (9th July to 4th November), the weekly rainfall has been greater than the weekly pan evaporation during 11 weeks. However during six weeks, 3-9 September, 10-16 September, 17-23 September, 24-30 September, 22-28 October, and 29th October to 4th November, the weekly pan evaporation has been greater than the weekly rainfall. Figure 5 clearly depicts the continuous dependence of rice fields on all the three sources of water viz. tube well, canal, and rain.

Table 14. Percent of rice fields dependent on tube well, canal, and rain waters during Kharif 1999 in Alipur and Rampur villages.

Standard weeks	Percent distribution of farmers' fields dependent on different sources of irrigation water		
	Canal	Tube-well	Rain
9-15 July	44.0	33.0	22.0
16-22 July	10.0	45.0	45.0
23-29 July	30.0	39.0	30.0
30 July-5 Aug	44.0	36.0	20.0
6-12 Aug	63.0	13.0	24.0
13-19 Aug	58.0	13.0	29.0
20-26 Aug	60.0	5.0	35.0
27 Aug-2 Sept	53.0	0.0	48.0
3-9 Sept	68.0	5.0	28.0
10-16 Sept	53.0	21.0	26.0
17 -23 Sept	16.0	29.0	54.0
24 -30 Sept	29.0	13.0	58.0
01-07 Oct	92.0	8.0	0.0
08-14 Oct	100.0	0.0	0.0
15-21 Oct	95.0	5.0	0.0
22-28 Oct	95.0	5.0	0.0
29 Oct -04 Nov	39.0	5.0	55.0

Fig.5: Percent of rice fields' dependent on tube well, canal, and rain waters in different standard weeks during Kharif-99 in Alipur and Rampur

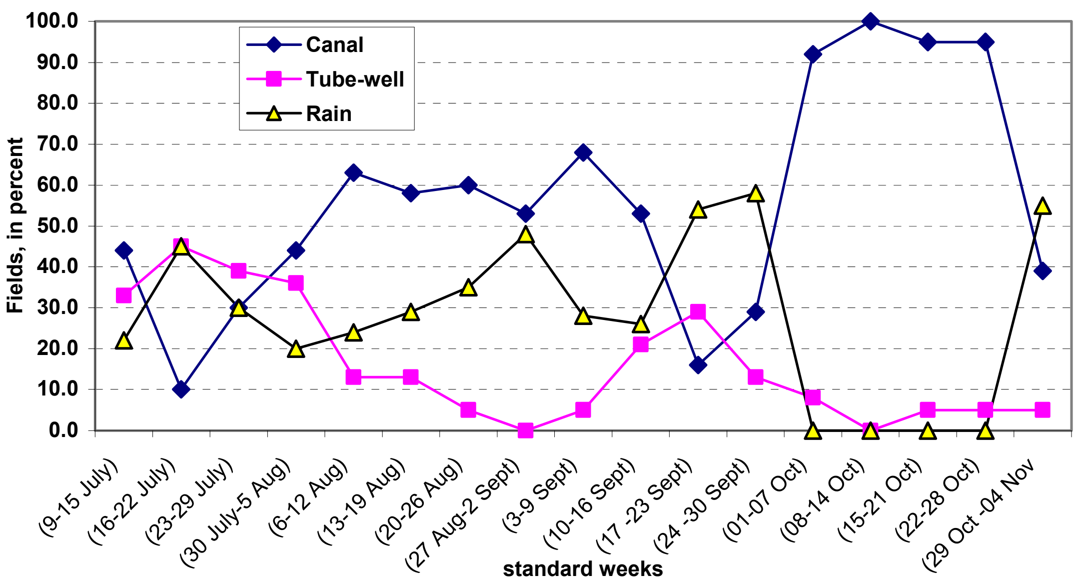


Table 15. Weekly rainfall (mm) and pan evaporation during Kharif 1998 and 1999

Std. Week	Date	Rainfall (mm), 1998	Rainfall (mm), 1999	Weekly Pan evaporation (mm), 1999
24	June 11-17	0.0	43.0	30.28
25	June 18-24	38.0	147.6	29.72
26	June 25-1 July	20.0	45.8	16.09
27	2-8 July	112.2	18.6	26.09
28	9-15 July	134.2	157.4	15.80
29	16-22 July	75.6	58.3	26.10
30	23-29 July	4.0	69.0	17.13
31	July 30-5 August	71.0	70.6	21.44
32	6-12 August	17.4	79.0	23.93
33	13-19 August	131.8	37.4	18.47
34	20-26 August	32.2	77.8	16.79
35	August 27-2	82.6	73.0	25.19
36	Sept.	51.3	6.2	26.32
37	3-9 September	25.8	25.0	27.03
38	10-16 September	177.6	11.2	27.71
39	17-23 September	62.	5.8	24.84
	24-30 September			
40	September 1-7	42.6	84.4	20.08
41	Oct	6.4	25.2	19.69
42	8-14 October	10.8	36.0	14.73
43	15-21 October	0.0	0.0	19.09
	22-28 October			
44	29 October -4	0.0	0.0	15.28
45	Nov.	37.4	0.0	14.89
46	5-11 Nov.	12.4	0.0	10.34
47	12-18 Nov.	0.0	24.0	13.93
	19-25 Nov.			
48	Nov. 26-2 Dec	0.0	0.0	15.05

Table 16 contains information about the number of tube-well irrigations applied to rice fields. As evident from the table, the number of fields receiving 0, 1, 2, 3, and 4 irrigations are, 45, 26, 18, 5, and 5 percents, respectively.

Fig.6: Number of tube-well irrigation versus date of transplanting

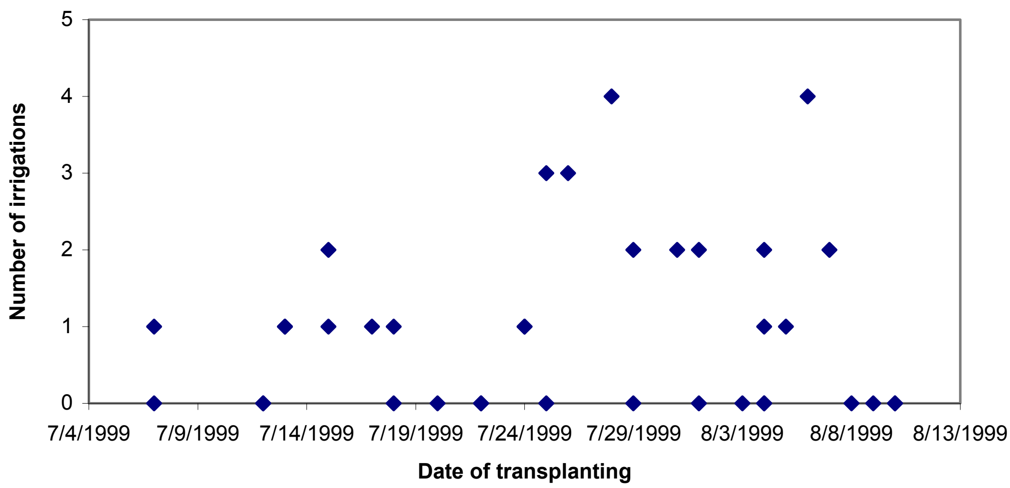


Table 16. Tube-well irrigation to rice fields in village Rampur and Alipur during Kharif 1999

No. of irrigations	No. of fields	Percent of fields
Zero	17	45
One	10	26
Two	7	18
Three	2	5
Four	2	5

A perusal of scattered diagram shown in Fig.6 reveals that most of the area transplanted upto 24th July, 1999 was given only one tube well irrigation, except one field which was irrigated twice. Most of the rice fields transplanted after 24th July have been irrigated one to four times using tube well water. Many rice fields transplanted through out the season were not given tube well irrigation probably due to availability of water from other sources.

Effect of Transplanting Dates on Rainwater Utilization in Rice Production

Kharif rice is normally transplanted and harvested during June 11 to December 2 coinciding with standard 24th to 48th weeks. The nursery for such rice is raised about 24 to 30 days prior to transplanting. Consequently, the rainfall during the 24th to 48th weeks has been taken as seasonal rain. The rain water utilization by rice crop transplanted on June 25 to July 1, July 23 to 29, and August 20 to 26th corresponding to 26th, 30th, and 34th weeks during the Kharif season 1999 was 1011.5 mm (84.2%), 649.1 mm (54%), and 390.2 mm (32.5%), respectively (Table 17). The corresponding figures for the Kharif 2000 are 76.2%, 52.3%, and 27.4%. The average rainwater utilization for 40 years (1960-1999) is also reported in Table 17. The average seasonal rainwater use in crop production by rice transplanted on June 25 to July 1, July 23 to 29, and August 20 to 26 as depicted in Figure 6 is 965.2mm (94.25%), 664.2mm (64.9%), and 423.0mm (41.3%), respectively. It may be remembered that only a part of the rainwater is utilized in meeting the requirements of evapotranspiration, degree of submergence, and deep percolation in rice production system.

Table 17. Effect of date of transplanting rice on rainwater utilization during 1999 and 2000

Date of transplanting, standard week	Seasonal rain water utilization in rice production, mm		
	1999	2000	Forty years average
26 June 25-July 01	1011.5	757.0	965.2
27 (02-08)	950.3	714.6	905.3
28 (09-15)	918.0	651.9	834.4
29 (16-22)	772.4	582.4	741.3
30 (23-29)	649.1	519.8	664.2
31 July 30-Aug 05	604.8	485.6	589.3
32 (06-12)	479.2	453.9	524.3
33 (13-19)	413.0	307.3	471.0
34 (20-26)	390.2	272.3	432.0

Rainfall between June-11 to December-02

For the year 1999 = 1202mm

For the year 2000 = 993mm

Forty years average=1024 mm

Effect of Transplanting Dates on Rice Yield

The effect of dates of transplanting on rice yield, as observed in farmers' fields during Kharif 1999 and 2000, is reported in Table18 and Appendix R 2. The yields were recorded by scientifically conducting crop harvest in 3 m x 3 m area in farmers' fields of different villages. Most of the farmers had adopted the full package of rice production technology. The crop harvest data of 1999 was obtained with the help of the farmers in the commands of RP Channel-5 and Majhauli distributaries. Each data point of 1999 is an average of several harvests. The crop harvest data of Kharif 2000 was obtained with the help of two research assistants. Each data point of 2000 is an average of 2 to 5 harvests.

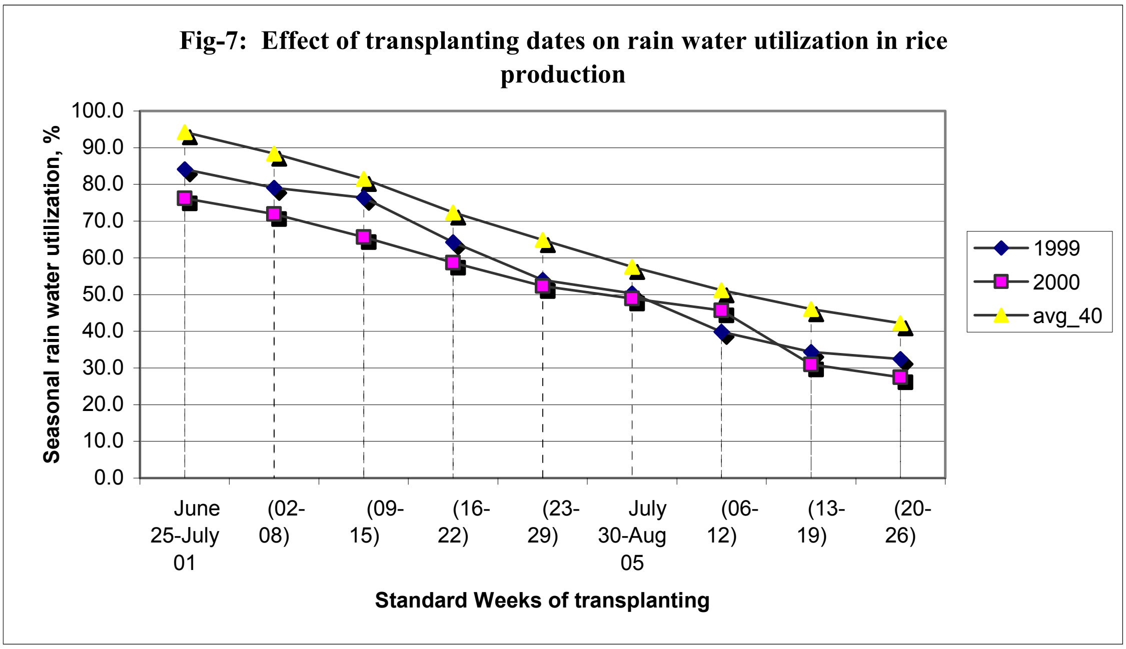


Table18. Effect of date of transplanting rice on crop yield during 1999 and 2000

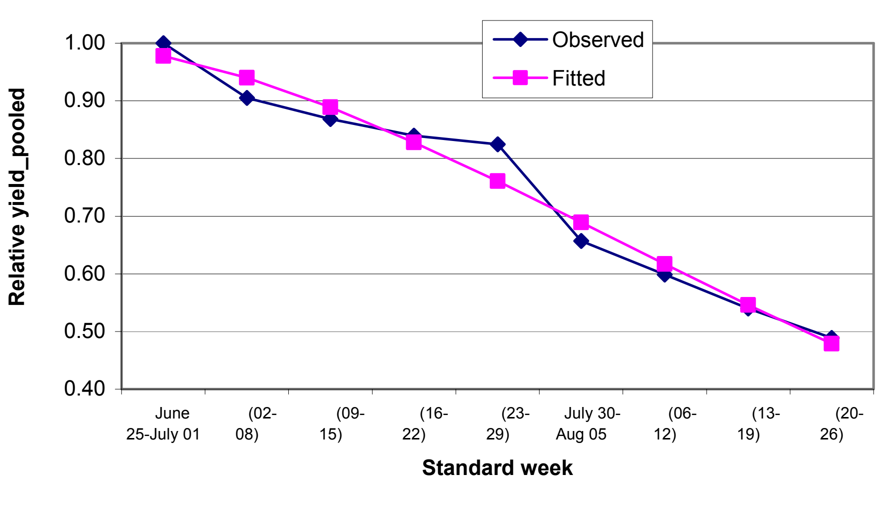
Date of transplanting rice, standard week	Rice yield during the year, t/ha			Reduction in yield in succeeding week, t/ha	Computed relative yield
	1999	2000	Pooled		
26 June 25-July 01	6.7	7.0	6.85		0.98
27 (02-08)	6.5	5.9	6.20	0.65	0.94
28 (09-15)	6.2	5.7	5.95	0.45	0.89
29 (16-22)	5.9	5.6	5.75	0.25	0.83
30 (23-29)	5.5	5.8	5.65	0.10	0.76
31 July 30-Aug 05	4.9	4.1	4.50	1.10	0.69
32 (06-12)	4.1	4.1	4.10	0.40	0.62
33 (13-19)	3.4	4.0	3.70	0.40	0.55
34 (20-26)	2.8	3.9	3.35	0.35	0.48

A perusal of Table 18 indicates the highest yield of rice when it was transplanted during June 25 – July 1 (26^{th} week). The yields of rice transplanted in subsequent weeks were lower than the planting done in 26^{th} week. Hence, the value of yields was divided by the highest yield and the relative yields were obtained. The relative pooled yields versus date of transplanting are plotted in figure 8. A third degree polynomial best fits the data on relative yield versus date of transplanting as below.

$$RY_P = 1.003 - (0.0143*week) - (0.00926*week^2) + (0.000488*week^3) \quad (1)$$

R^2=0.974

Figure 8. Effect of date of transplanting on relative pooled yield of rice during 1999-2000



In the first equation, week 1 is June 25-July1 and week 9 is August 20-26. The computed relative yields are also reported in Table 18. A perusal of Fig. 8 and Table 18 indicates the maximum yield of rice when transplanted during the 26th week (June 25-July 1). Transplanting of rice in weeks 27, 28, 29, and 30th causes reduction in yield to its preceding week values by about 4, 5, 6, and 7 percents, respectively. Thus the yield of rice transplanted in the 30th week (July 23-29) is approximately 76% to the yield of rice transplanted in 26th week (June 25-July 01). Transplanting in 31st week (July 30 to August 5) results in reduction of over 7 per cent yield in comparison to rice transplanted in 30th week (July 23-29). Any further delay causes reduction in yield to the tune of approximately 7 percent per week.

Identification of Wheat Production Constraints

A group of scientists from the Directorate of Water Management Research, Patna, and Center for Environment, Agriculture and Development, New Delhi identified the major constraints to wheat production as delay in sowing arising from late harvesting of rice, excess soil moisture regime due to delayed rains as well as release of canal water, and inadequate mechanization for early land preparation and seeding. Group meetings with the farmers helped in identifying other production constraints as (i) non-availability of appropriate varieties of wheat seeds; (ii) imbalanced use of fertilizers; (iii) lack of awareness about seed treatment and weed management practices; (iv) non-availability of zero-till seed drill and harvesting equipment; and (v) lack of proper technical guidance and demonstration by the development departments.

Improved Wheat Production Technology

Delayed sowing of wheat is one of the major constraints in the command of Sone canal system that results in low crop yields. Farmers were advised to use zero-till seed drill for proper placement of seed as well as basal fertilizers. Weed infested fields were ploughed once before seeding using either a tractor drawn cultivator or a country plough. No ploughing was done to the fields having lesser weeds, and seeds were sown directly by zero-till seed drill. In this way the farmers were able to save ten to fifteen days on land preparation. Seed rate of 120 kg/ha for early sowing, and 140 kg/ha for late sowing was recommended.

Scientists of the Directorate of Water Management Research, Patna, and Center for Environment, Agriculture, and Development, New Delhi organized several training camps (Table 3) about the improved wheat production technology in different villages. Farmers were advised to use a balanced dose of N: P: K at the rate of 120:60:40 kg/ha. Thus in one hectare 210 kg urea, 130 kg DAP and 65 kg muriate of potash were applied. A full dose of phosphorus (130 kg DAP), potash (65 kg MOP) and half a dose of urea (105 kg) were applied at the time of sowing as basal dose and the remaining urea was applied in two-split doses at the time of first and second irrigation.

Phalaris minor, a narrow leaf weed resembling wheat plant, was the major weed infesting wheat fields, sometimes up to 60 % of the total plant population. In order to control this menacing weed, Isoproturan @ one kg a.i./ ha was applied between 30-35 days after sowing the wheat crop. However, for controlling the narrow and broad leaf weeds, 300 gm Isoproturan and 400 gm 2,4-D/ ha a.i. were applied 30-35 days after sowing of the crop.

In the absence of the field channels, the farmers of the Sone canal command apply uncontrolled field-to-field irrigation to rice as well as wheat crops. In this way they apply heavy watering to the cropped fields, and make wasteful use of water. The farmers were advised to apply light irrigation of 5-7 cm so as to avoid stagnation of irrigation water in the cropped field for more than 12 hrs as wheat crop is affected by water logging. They were further advised to follow the following irrigation schedules as per the availability of water:

One- irrigation only	:at the time of crown root initiation (CRI) stage, 21-25 days after sowing;
Two irrigations	:CRI + flowering stage which occurs at 60-65 days after sowing;
Three irrigations	:CRI + booting stage which occurs at 40-45 days after sowing + flowering stage
Four irrigations	:CRI + booting + flowering + dough stage, which occurs at 80-85 day after sowing.

Depending upon the availability of irrigation water, it is evident that a maximum of four irrigations at an interval of 20-25 days are required to alleviate moisture stress to wheat crop.

Effect of Date of Sowing of Wheat on Crop Yield

Wheat is highly sensitive to soil and ambient thermal regimes. Its optimum sowing time has been considered to be the middle of November when winter has just set in. The three years (1998, 1999, 2000) average (maximum, minimum) temperatures at Patna during Nov 5-11, Nov 12-18, Nov 19-25, and Nov 26 to Dec 02 has been observed to be (30.3,17.7), (28.1,16.3), (27.8,15.8), and (26.9,12.1) ^{0}C, respectively.

In order to study the effect of date of sowing of wheat on crop yield (Plate 14), crop harvest data of wheat sown in the standard weeks of November 19-25, November 26 to December 2, December 3-9, Dec. 10 –16, Dec. 17-23, and Dec. 24-31 during the years 1999-2000, and 2000-2001 were collected from the farmers' fields located in several villages and distributary commands. Even though the soils in all the villages are alluvial, they have variable textural distributions. The methods of sowing and other crop production inputs were variable as per practices adopted by different farmers. The data were scientifically collected from 3 m x 3 m area by randomly locating it in the farmer's field. The observed crop yield data has been corrected at standard moisture content of 12 per cent.

Table 19 gives the effect of date of sowing of different wheat cultivars on crop yield during the Rabi seasons of 1999-2000, and 2000-2001. The table also gives the average yield of two crop seasons. The plots of wheat yield for the crop season of 1999-2000, 2000-2001 versus standard week, and the average yield versus standard week are depicted in figure 9. Wheat sown during the period November 19-25 has yielded maximum in both the crop seasons of 1999-2000 as well as 2000-2001. Likewise, the wheat sown during the week Dec 24-31 has yielded the minimum. As evident from Table 20 and Figure 9, the yield has drastically declined between these two periods. Figures 10, 11, 12 give graphical representation of relative yield versus standard week for the data given in Table 20. The best-fit curve obeys the following relationship:

$$Ry_w\ (1999\text{-}2000) = 1.18 - (0.249 * \text{week}) + (0.0643 * \text{week}^2) - (0.00667 * \text{week}^3) \quad (2)$$

$R^2 = 0.970$

$$Ry_w\ (2000\text{-}2001) = 1.22 - (0.241 * \text{week}) + (0.0223 * \text{week}^2) - (0.000556 * \text{week}^3) \quad (3)$$

$R^2 = 0.982$

$$Ry_w\ (\text{average}) = 1.25 - (0.323 * \text{week}) + (0.0682 * \text{week}^2) - (0.00583 * \text{week}^3) \quad (4)$$

$R^2 = 0.972$

In which

Ry_w = relative yield of wheat

$$= \frac{\text{average yield of wheat sown during a week}}{\text{maximum observed average yield of wheat sown in any week}} \quad (5)$$

In equations (2), (3), and (4), the period of November 19-25 is week 1 and that of December 24-31 is week 6. As the yield of wheat sown during November 19-25 is maximum, the relative yield is obtained by dividing the yield data by the maximum yield of November 19-25.

Table 19. Effect of date of sowing of wheat (all varieties) on crop yield during 1999-2002 and 2000- 2001

St. Week	Yield (q/ha) 1999-2000	Relative yield 1999-2000	Yield (q/ha) 2000-2001	Relative yield 2000-2001	Two crop season average yield q/ha	Actual relative average yield	Predicted relative average yield
Nov.19-25	53.89	1	56.11	1	55	1	0.99
Nov. 26-2	45.87	0.851	41.66	0.831	43.76	0.80	0.83
Dec.3-9	46.12	0.855	36.21	0.645	41.16	0.75	0.74
Dec 10-16	43.52	0.807	34.9	0.621	39.21	0.71	0.68
Dec. 17-23	36.50	0.677	26.39	0.47	31.44	0.57	0.61
Dec. 24-31	30.78	0.571	26.33	0.463	28.55	0.52	0.55

The relative yield is a measure of the fraction of maximum yield that has been achieved by sowing wheat in different weeks. As the data have been collected from the farmers' fields spread over several villages, it may be taken as the representative for the area. In the absence of planned experiment, the yield data of wheat sown earlier than the week of November 19-25 could not be taken. The yield collected from 3m x 3m sampled-area contains sampling errors. However, the relative yield is expected to eliminate some of the errors. Figure 10 indicates the decline in wheat yield in comparison to the maximum yield of November 19-25 by 11, 17, 21, 29, and 44 percents, respectively, when sown during the weeks November 26-December 2, December 3-9, December 10-16, December 17-23, and December 24-31 during the Rabi season 1999-2000. The corresponding yield reductions (Fig.11) during the Rabi season 2000-2001 were 18, 14, 10, 8, and 4 per cents, respectively. The average yield reductions of the two Rabi seasons (Fig.12) due to delayed sowing during November 26-December 2, December 3-9, December 10-16, December 17-23, and December 24-31 in comparison to the maximum yield of November 19-25 have been computed to be 16, 26, 29, 38, and 48 percents, respectively. The analysis shows the fastest decline in wheat yield when sown during the weeks of November 26-December 2, and December 3-9.

The effect of date of sowing of wheat of cultivar Kundan during 2000-2001 is presented in Table 20 and Figure 13. As evident from the figure, the yield decline almost follows the same trend as in figures 9, 10 and 11 for all the varieties of wheat.

*Table 20. Effect of date of sowing of wheat (Kundan) on crop yield during 2000-***01**

St. Week	Av.yield (q/ha)	Actual relative yield	Predicted relative yield
Nov.19-25	56.11	1	0.985
Nov. 26-2	41.66	0.74	0.785
Dec.3-9	38.67	0.68	0.665
Dec 10-16	35.52	0.63	0.591
Dec. 17-23	26.8	0.47	0.528
Dec. 24-31	25.98	0.46	0.441

Figure 9. Effect of date of sowing of wheat on crop yield during 1999-2000 and 2000 -2001

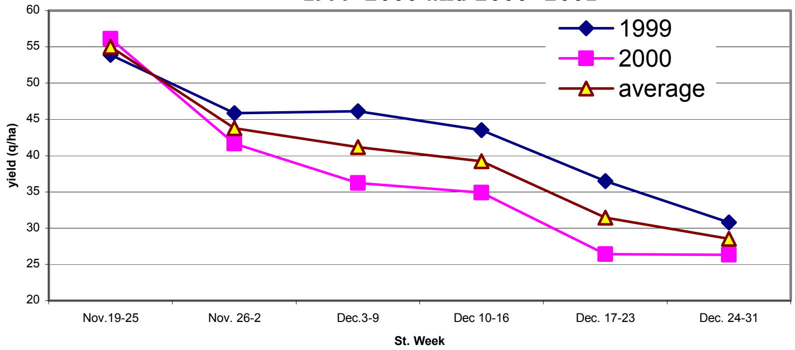


Figure 10. Effect of date of sowing on wheat yield during 1999-2000

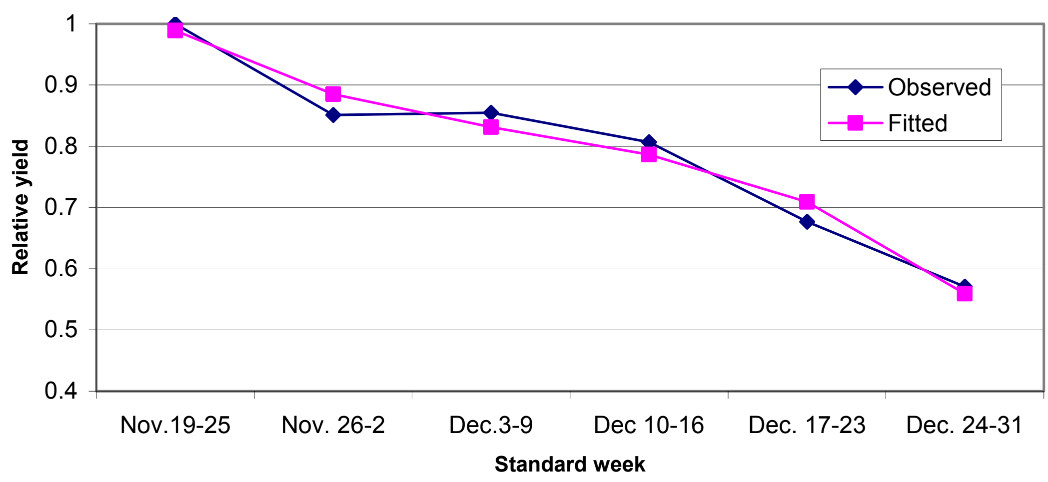


Fig.11 Effect of date of sowing on relative wheat yield during 2000-01

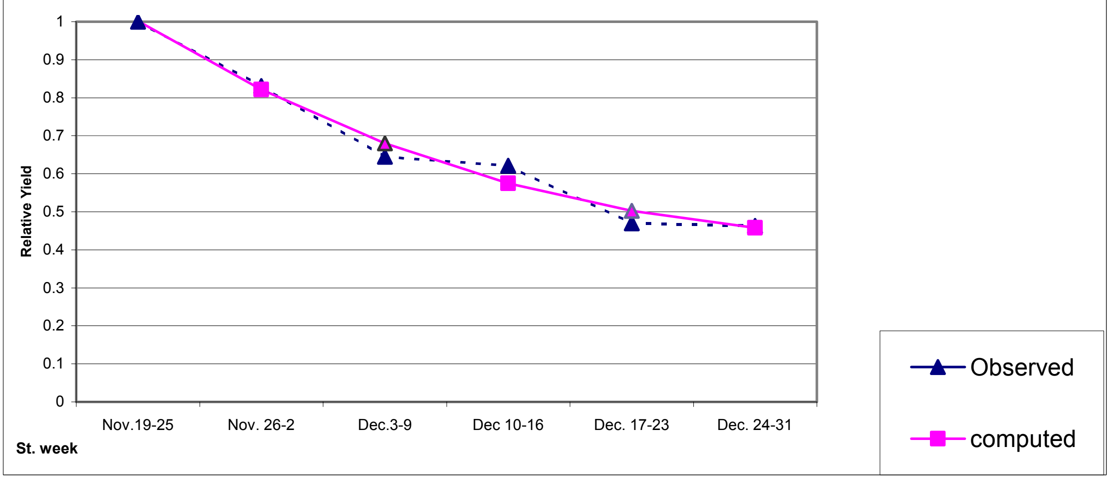


Figure 12. Effect of date of sowing on relative pooled yield of wheat during 1999-2000 and 2001

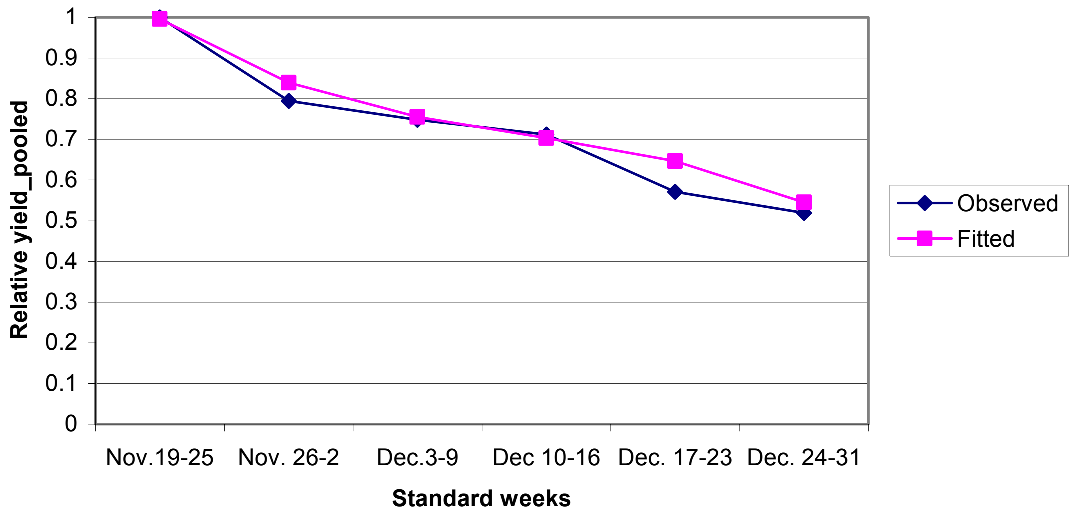
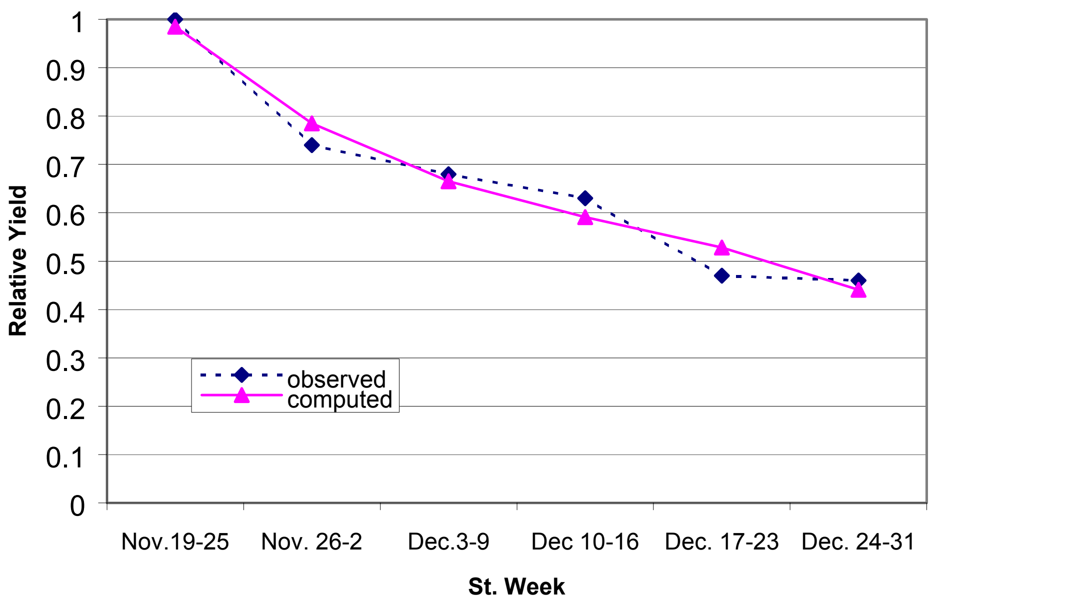


Fig. 13 Effect of date of sowing on wheat (Variety kundan) yield during 2000-01



Relative yield= 1.301- (0.385*Week)+ (0.0751*Week^2) –(0.00580*Week^3), R^2=0.982

Conclusion

Increase in rice and wheat yields in the commands of Sone Canal network has been demonstrated employing system approach to the crop production system. Early nursery raising and transplanting of rice helped its early harvesting, thereby making the fields available for timely sowing of wheat. During the years 1999 and 2000, scientists from the Directorate of Water Management Research, Patna and Centre for Environment, Agriculture and Development, Post Box No.11321, IARI, New Delhi-12 organized 118 training camps in the commands of RP Channel-5 and Majhauli distributary to educate them about the timeliness of seeding and planting, improved rice-wheat production technology and other aspects of agricultural production system. In these training camps, more than 6447 farmers participated.

The training helped the farmers in adoption of improved rice and wheat production technologies. During Kharif 1999, the farmers of 15 villages in the commands of RP Channel-5 and Majhauli distributaries adopted timely sowing of rice nursery using tube well water sufficient for transplanting 40 ha area. They followed the recommended fertilizer and pest management practices which helped in getting bumper harvest of as much as 6.70 tons / ha. The bumper production motivated the farmers in the commands of other five distributaries to approach the Directorate of Water Management Research and Centre for Environment, Agriculture, and Development, Post Box No.11321, IARI, New Delhi-110 012 for their adoption to get training about crop production technologies. Consequently during Kharif 2000, the farmers in the commands of seven distributaries followed the improved methods of rice production in 480 ha spread in 86 villages and partial adoption in 8994 ha in 102 villages. During Rabi 1999-2000, the farmers of 17 villages adopted the improved wheat production technology, including the use of zero-till seed drill, in 55 ha. The study leads to the following major conclusions.

1. Rice transplanted during the week 25th June to 1st July in Kharif 1999 and 2000 gave consistently highest average yield of 6.85 t/ha. A delay of two weeks till 15th July, and four weeks till 29th July resulted in yield reduction of 11 per cent and 24 per cent, respectively. Late transplanting during the week 20-26th August caused 52 per cent reduction in rice yield.
2. In order to achieve high crop yields, timely seeding of rice nursery is essential. It is possible only with the help of groundwater. Thus installation of a large number of shallow tube wells in the canal commands is essential for creating favorable soil moisture regime for rice-wheat and other production systems.
3. Delayed transplanting not only causes reduction in paddy yield, but also requires more irrigation from tube-wells. It entails more expenditure on diesel, as the farmers are required to irrigate entire transplanted area. On the other hand, timely transplanted rice requires less irrigation from tube-wells after transplanting, but requires 2-3 irrigations to rice nursery sown in 1/10th of the transplanted area.
4. Analysis of data of rainfall stretching over 40 years that transplanting of rice during the weeks of June 25 – July 01, July 09 – 15, and July 23-29 utilizes respectively 94.3, 81.5, and 64.9 per cent seasonal rainwater in rice production. Transplanting rice during the weeks August 6-12 and August 20-26 utilizes 51.2 and 42.2 per cent seasonal rainwater in crop production. Thus, late transplanting not only causes low yields, but also results in less utilization of seasonal rainwater in rice production.
5. Sowing of wheat in the weeks of November 19-25 yielded maximum crop yield of 5.5 tons/ha. Delay in sowing in the weeks December 3-9, and December 17-23 reduced crop yields by 26 and 38 percent, respectively. Sowing in the weeks December 24-31 reduced crop yield by 48 per cent.

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