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Special Section

Technological Interventions: Boon for Rice production in Konkan Region

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Abstract

Rice is one of the premier cereal crops of the World and staple food of more than half of the World's population. In India, introduction of semi-dwarf high yielding varieties was instrumental in increasing the rice production. The steady increase in rice production over the years transformed the country from food deficit to net surplus. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli has released and notified 25 rice varieties including 5 hybrids and has developed improved package of practices for cultivation of rice crop since 1972. The rice production has increased from 10.06 lakh tonnes (1970) to 15.69 lakh tonnes (2016) and productivity from 2.3 t·ha^{-1} to 4.35 t·ha^{-1}.

Keywords: Rice varieties, Package of practices, Doubling Farmers' Income, DFI

Rice Scenario

Rice is staple food of India as well as Asia, Latin America, part of Africa and the Middle-East. In India, rice cultivation is taken below sea level (Kerala) up to altitude of 2000 m above MSL (Kashmir). It plays vital role in national food security and it is means of livelihood of millions of people making a slogan "Rice is Life" most appropriate.

Globally, the highest area under rice is in India (43.86 million ha) followed by China (30.16 million ha) However, highest production of rice is in China (144.85 million tonnes) followed by India (104.80 million tonnes). This is due to higher productivity of rice in China (6.86 t ha^{-1}) than India (3.77 t ha^{-1}) (Table 1) (Anon. 2017)

In India, rice is cultivated in both winter and summer seasons. West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Bihar, Orissa, Assam, Karnataka & Haryana are 10 major rice producing States which account for more than 80 per cent rice production in India (Table 2) (Anon. 2016). More than 5000 varieties of rice are grown in India. India is world's largest exporter of Basmati rice to Saudi Arabia and other Middle-East countries, Europe and United States (Anon. 2009).

In Maharashtra, rice is cultivated on 15.56 lakh ha area in all four regions *viz*. Vidarbha (8.15 lakh ha), Konkan (3.69 lakh ha), Western Maharashtra (3.55 lakh ha) and Marathwada (0.156 lakh ha). The highest productivity of rough rice was in Konkan region (4.25 t ha^{-1}) followed by Western Maharashtra (3.5 t ha^{-1}) and Vidarbha (3.4 t ha^{-1}) (Table 3) (Anon. 2017).

The rice production in Maharashtra in 1960 was 19.84 lakh tonnes which increased to 52.96 lakh tones in 2016 (Table 3). Thus during last 56 years the rice production has been increased by 5 times. The rice productivity in 1960 was 1.52 t ha^{-1} and it has increased to 3.4 t ha^{-1} in 2016 (Anon. 2017). This increase in rice production and productivity was due to cultivation of newly released

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Table 1. Area, production and productivity of rice in various countries of the world (2016-17) (Anon. 2017)

Sr. No.	Country	Area (million ha)	Production (million tonnes)	Productivity Rough Rice (t ha^{-1})
1.	China	30.16	144.85	6.86
2.	India	43.86	104.80	3.77
3.	Indonesia	12.24	37.15	4.78
4.	Bangladesh	11.77	34.58	4.41
5.	Vietnam	7.70	27.86	5.79
6.	Thailand	10.08	18.60	2.80
7.	Burma	7.00	12.40	2.77
8.	Phillipines	4.60	11.50	3.97
9.	Brazil	2.00	8.16	6.00
10.	Japan	1.57	7.78	6.81
11.	United States	1.25	7.12	8.11
12.	Pakisatan	2.69	6.80	3.80
	Total World	159.91	483.1	4.50

Table 2. Statewise area, production and productivity of Rice in India. (Anon. 2016)

Sr. No.	State	Area (million ha)	Production (million tonnes)	Productivity (t ha^{-1})
1.	West Bengal	5.39	14.71	2.73
2.	Uttar Pradesh	5.87	12.22	2.08
3.	Andhra Pradesh	3.81	11.57	3.04
4.	Punjab	2.89	11.11	3.84
5.	Orissa	4.17	8.29	1.99
6.	Bihar	3.27	6.38	1.95
7.	Chattisgarh	3.81	6.02	1.58
8.	Tamil Nadu	1.83	5.84	3.19
9.	Assam	2.28	4.86	2.13
10.	Haryana	1.29	4.01	3.11
11.	Karnataka	1.30	3.66	2.82
12.	Madhya Pradesh	2.15	3.63	1.69
13.	Jharkhand	1.50	3.32	2.21
14.	Maharashtra	1.55	2.93	1.89
15.	Gujarat	0.79	1.64	2.08
16.	Kerala	0.20	0.56	2.80
17.	Other	1.78	4.07	2.29
	All India	43.86	104.80	2.44

rice varieties and hybrids grown under recommended package of practices.

Konkan region of Maharashtra has 5 districts viz. Thane, Palghar, Raigad, Ratnagiri and Sindhudurg. Agroecologically the Konkan region is a part of hot-humid ecoregion consisting Sahyadri mountain and Western coastal plains extending over state of Maharashtra, Goa, Karnataka and Kerala (Sehgal *et al*. 1992). Highest productivity in Konkan is in Sindhudurg district (4.89 t ha^{-1}) followed by Ratnagiri (4.66 t ha^{-1}), Palghar (4.1 t ha^{-1}), Raigad (3.99 t ha^{-1}) and Thane (3.88 t ha^{-1}) (Table 4).

Technology Development in India –Historical

ICAR supported research stations have been the backbone of technology development for rice in India. These research stations collected the local rice varieties, evaluated them under their local conditions and identified the best performing varieties. Initially, to increase production and productivity, more than 445 varieties were recommended by pure-line selection for preference over the local landraces. Given the negligible use of chemical fertilizers and/or insecticides in pre-independence era, the improved varieties were mostly bred under (and were adapted to) low input conditions only.

After the establishment of the Central Rice Research Institute (CRRI) at Cuttack in 1946 by the Government of India, rice research and training received an added impetus. The traditional rice varieties already collected and maintained by the various rice research stations in the country were screened for their yield potential.

Meanwhile, the ICAR launched the All-India Coordinated Rice Improvement Project (AICRIP) in 1965 that helped in co-ordinating interdisciplinary and interinstitutional rice research within the country for improving production, productivity and profitability of rice in India. This was the beginning of moving toward self-sufficiency in rice production (Swarna *et al*. 2010).

India operated its most intensive rice breeding program under the AICRIP and achieved remarkable success. Padma and Jaya were the first two varieties that emerged from the programme. During the span of next 35 years (1965 to 2000), 632 high yielding rice varieties were released by the Central Variety Release Committee and by the State Variety Release Committees. These Varieties were bred for various ecological stress situations, or to meet the new challenges faced due to diseases and insect pests which were earlier minor but became major, or for

Table 3. Information on Area, Production and Productivity of rough rice in Maharashtra State

Regions	Area (lakh ha)		Rough Rice Production (lakh t)		Rough Rice Productivity (t ha^{-1})	
	1960	2016	1960	2016	1960	2016
Konkan	4.17	3.69	7.65	15.69	1.83	4.25
Western Maharashtra	2.82	3.55	4.26	12.77	1.51	3.50
Vidarbha	5.21	8.15	7.08	24.46	1.36	3.40
Marathwada	0.80	0.15	0.84	0.028	1.05	0.48
Maharashtra State	13.00	15.56	19.84	52.96	1.53	3.40

Table 4. Second advance Estimate of Area, Production (P) & Productivity (Py) of Kharif rice in Konkan region, Maharashtra during 2016. Area in "00" ha, P in "00" Tonnes, Py in t ha^{-1}.

Sr. No.	District	Area	Rice		Rough Rice	
			P	Py	P	Py
1	Thane	551	1476	2.679	2139	3.882
2	Palghar	756	2172	2.873	3147	4.163
3	Raigad	1094	3017	2.758	4372	3.997
4	Ratnagiri	686	2203	3.214	3192	4.658
5	Sindhudurg	604	1958	3.242	2837	4.698
	Total	3690	10827	2.934	15691	4.252

Table 5 Rice varieties developed and released by RARS, Karjat from 1919 to 1970.

Sr. No.	Variety (Parentage)	Year of release	Duration in Kharif (days)	Grain type	Yield (q ha^{-1})
Rice varieties developed by pure line selection method					
1.	Kolamba-42	1924	130-135	SS	29
2	Zinia-31	1934	125-130	SS	24
3	Zinia 149	1934	145-150	MS	29
4	Kada-68-1	1946	115-120	LB	24
5	Mahadi 4-4	1954	115-120	LB	24
6	Garvel 1-8	1954	150-152	LB	23
Rice varieties developed by hybridization followed by selection method					
1	Kolamba-540 (K-164 x K -26)	1934	130-135	SS	24
2	Bhadas-1303 (1-B-12-11 x C-48)	1954	135-140	SB	37
3	Zinia 14 ((K-226 x Z-242) x (Z-149 x K-540)	1958	145-150	MS	33
4	Zinia-63 (Z-31 x K-540) x (Z-149)	1959	125-130	SS	25

grain quality especially the Basmati types for export (Prasad Rao 2004).

Research programme was initiated in early 1970 to develop hybrid rice in the country. However, there was no breakthrough in this program for two decades. The research program was accelerated and intensified from 1989 onwards with a mission mode project. With this concerted research effort, a remarkable success was achieved within a short span of five years and half a dozen hybrid rice varieties were developed from public and private sectors. The first four hybrid rice varieties were released in the country during 1994. By the end of 2016, a total of 76 hybrid varieties were released (Anon. 2016).

Regional Agrilcultural Research Station (RARS), Karjat was established by British Government in 1919 for development of rice varieties for Raigad & Thane districts. From this period RARS, Karjat has developed and released six rice varieties by Pure-line Selection (Table 5) and four rice varieties by hybridization. These varieties have productivity of 24 to 37 q ha^{-1}. In Maharashtra total 62 rice varieties have been released including 5 hybrids by four Agricultural Universities.

Interventions by Dr. Balasaheb Konkan Krishi Vidyapeeth, Dapoli

Varietal development

After establishment of Dr. Balasaheb Konkan Krishi Vidyapeeth, Dapoli in 1972 University has released and notified 25 rice varieties including 5 hybrids. Rice varieties having Productivity 3 to 5 t ha^{-1} and hybrids having productivity 5.5 to 7.5 t ha^{-1}. (Table 6)

Among these rice varieties, Karjat-3 and Karjat-7 are largely accepted varieties by farmers. Karjat-3 is short duration (115-120 days), short bold grain, high yielding (4.5-5.0 t ha^{-1}) rice variety accepted by all districts (Thane, Palghar, Raigad, Ratnagiri and Sindhudurg).

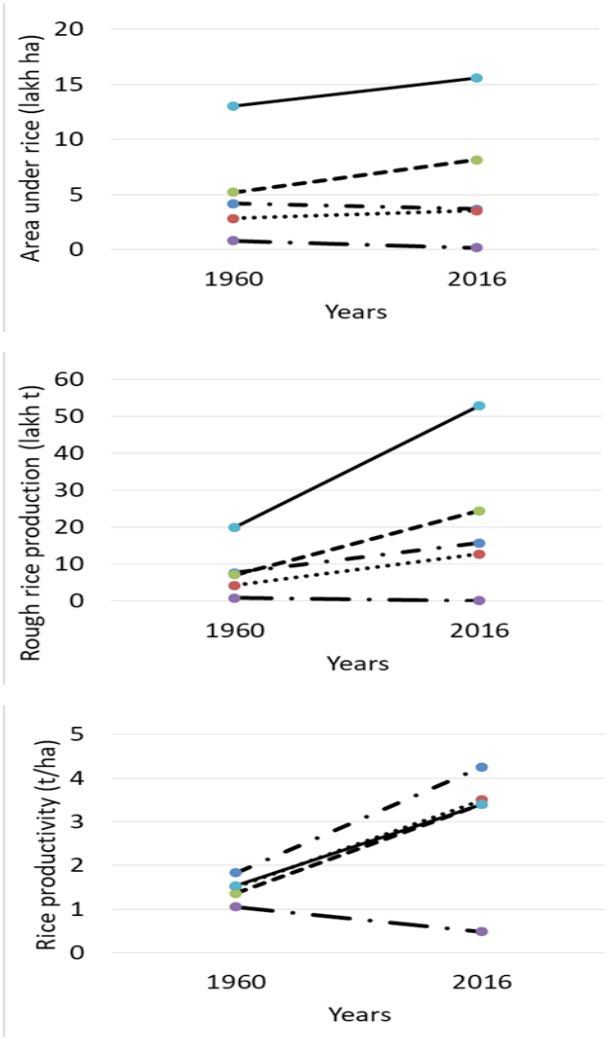
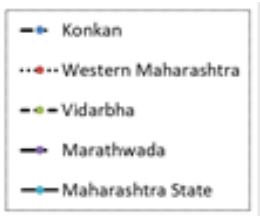


Fig. 1. Change in area, production and productivity of rice in Maharashtra state and its various regions.



It is also accepted by farmers of Goa. The seed of this variety is used for *poha* making, *bhakri* and grains (food). Karjat-7 is also short duration (115-120 days), long slender grain with high yield (4.5-5.0 t ha^{-1}) accepted by farmers. In 2016, among all the varieties whose seed was supplied in Maharashtra, Karjat-3 (4345 q) and Karjat-7 (3396 q) followed Jaya (5921 q) (Table 7).

Karjat-5 is a mid-late duration (125-130 days) variety with high yield (45-55 q ha^{-1}) having long bold grains. This variety has been accepted in Raigad district on small scale. Karjat-8 and Karjat-9 are newly released (notified) very fine grain (short slender) rice varieties accepted by farmers. Due to short slender grain of Karjat-8 and medium slender grain type of Karjat-9, these rice varieties are fetching higher price in market. RTN-1 and RTN-24 rice varieties are very much popular and accepted by farmers of Western Maharashtra (Kolhapur, Satara) region. Ratnagiri-5 is early duration (115-120 day) short slender grain type, good yielding (36 q ha^{-1}) notified rice variety, needs extensive extension programmes. Karjat-8 is late duration (140-145 days) short slender and Karjat-9 is midlate duration (120-125 days), medium slender rice variety. (Kunkerkar *et al*. 2014)

Among the limited available options to increase production and productivity of rice, hybrid rice is most practically feasible and readily adapatble one. University released five rice hybrids of early, midlate and late duration. Which is very popular in state as well as in country. Sahyadri is the 1st hybrid rice in Maharashtra having midlate duration (125-130 days), long slender grain type and average yield 6.5 to 7.0 t ha^{-1}. Moderately resistant to major pests and diseases, suitable for beaten rice & parched rice. Sahyadri-4 is centrally released hybrid having early duration (115-120 days) long slender grain type. Due to its wider adaptability in varied agro-ecological conditions and earliness it was recommended and released for commercial cultivation in five states of country *viz*. Punjab, Haryana, Uttar Pradesh, West Bengal and Maharashtra.

Package of practices

On various research stations of University, the research trials were conducted in various disciplenes. Agronomical trials for control of weeds, spacing & fertilizer trials, rice cropping systems etc. were conducted contionously for 3 to 4 years and recommendation emerged for increasing rice yield are summarized as below. In soil science discipline, the trials on use of organic, inorganic fertilizers, slow-releasing fertilizers, rice husk etc. were conducted & recommendations were given for increasing the rice yield. For control of insect pests and diseases, various plant protection measures were studied for rice and were recommendation. The integrated use of this technology by farmers results into increased in

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Table 6. Released and notified varieties of rice by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (1972 to 2016)

Variety	Year of release	Duration (days)	Yield (q ha^{-1})	Characteristics	Remarks
Ratnagiri-1	1986	110-115	47-50	Long bold grain, mid-tall, good tillering ability dark green foliage, non-lodging, non-shattering.	Notified No.SO.386-E 15.05.1990
Ratnagiri-2	1986	145-155	50	Short bold grain, mid-tall, good tillering ability, dark green foliage, non-lodging, non-shattering.	Notified No.SO.386-E 15.05.1990
Ratnagiri-3	1993	140-142	42	Late duration, mid-tall, non-lodging, non-shattering, long bold grain.	Notified No.SO.1-E 1.01.1996
Ratnagiri-4	2009	125-130	49	Long slender grain	Notified No.SO.2137-E 31.08.2010
Ratnagiri-24	2009	105-115	36	Short slender translucent grain, erect growing, compact panicle, mid tall, early variety wing light green narrow erect leaves.	Notified No.SO.2137-E 31.08.2010
Ratnagiri-73	1979	Kharif-95-98 Rabi- 120	45	Long bold grain, dwarf, very early, non-lodging variety with erect dark green leaves.	Notified No.SO.867-E 26.11.1986
Karjat-1	1985	105-110	35-45	Short bold grain, dwarf, non lodging, dark green foliage, early duration, non-shattering responsive to N fertilizers.	Notified No.SO.386-E 15.05.1990
Karjat-2	1993	135-140	40-45	Long slender, fine grain, dwarf, erect with dark green leaves, flag leaf erect.	Notified No.SO.1-E 1.01.1996
Karjat-3	1994	110-115	45-50	Short bold coarse grain, early, high yielding, medium tillering, erect flag leaf with dark green colour.	Notified No.SO.1-E 1.01.1996
Karjat-5	2006	125-130	43-53	Long bold grain, Resistant to blast	Notified No.SO.1703-E 5.10.2007
Karjat-6	2006	130-135	35-40	Fine grain Resistant to blast	Notified No.SO.1703-E 5.10.2007
Karjat-7	2007	Kharif 115-120 Rabi 130	45-50	Long slender grain	Notified No.SO.449-E 11.02.2009
Karjat-184	2009	100-105	30-35	Medium slender grain, early duration, short statured (70-75 cm height) broad dropping leaves, fine grain with blackish straw panicle colour.	Notified No.SO.2137-E 31.08.2010
Phondaghat-1	2000	115-120	45-50	Long slender grain, semi-dwarf, early, non-lodging, non-shattering.	Notified No.SO.1177-E 25.08.2005
Panvel-1	1984	125-130	40-43	Short bold, white kernel, semi-dwarf, mid-late, faint purple tinch at older leaf sheath.	Notified No.SO.540-E 24.07.1985

Table 6 continued...

Panvel-2	1987	110-115	33-41	Long slender and translucent grain, semi-dwarf, non-lodging, early duration non-shattering and salt tolerant.	Notified No.SO.386-E 15.05.1990
Palghar-1	1988	120-125	40-45	Medium slender grains, semi-dwarf, mid-late, high yielding.	Notified No.SO.386-E 15.05.1990
Sahyadri	1998	125-130	60-65	Long slender, grain, white kernel, slight aroma, mid-late, mid tall, non-lodging, non- shattering.	Notified No.SO.821-E 13.09.2000
Sahyadri-2	2006	115-120	60	Non lodging, mid tall (15 to 120 cm), midlate duration, long slender, translucent kernel.	Notified No.SO.122-E 6.02.2007
Sahyadri-3	2006	125-130	65-75	Long slender grain	Notified No.SO.122-E 6.02.2007
Sahyadri-4	2006	115-120	55-65	Long slender grain, wide adaptability, release for five state Panjab, Haryana, Uttar pradesh, West Bengal & Maharashtra	Notified No. 454-E 20.11.2009
Ratnagiri-5	2012	115-120	36	Short slender grain, moderately resistant to leaf blast	Notified S.O.2238E-23 Dated 29.6.2017
Sahyadri-5	2012	140-145	66	Long slender grain, moderately resistance to leaf blast, tolerant to brown plant hopper.	Notified S.O.2238E-24 29.6.2017
Karjat-8	2012	140-145	35-40	Short slender growth, moderately resistant to blast	Notified
Karjat-9	2014	120-125	45-50	Short slender grain, resistant to blast.	Notified

rice production and income.

Cultivation practices

1) In North Konkan coastal zone of Maharashtra for obtaining maximum yield and economic returns from Sahyadri rice hybrid, 25 days old seedlings be transplanted at 20 x 15 cm spacing with two seedlings per hill and be supplemented with fertilizer dose of 150:50:50 kg NPK ha^{-1}.

2) To get maximum yield and net profit from Rice-Maize cropping system, rice and maize crops be fertilized with 150:75:75 kg NPK ha^{-1} and 180:90:60 kg NPK ha^{-1} respectively.

3) To get higher yields and net returns from kharif rice 48 hours *Rahu* (sprouted seeds) of rice be sown by using 8 rows DRR drum seeder on puddled field.

4) In direct seeded rice for control of weed oxydiarzon 0.4kg a.i ha^{-1} or oxydiagil 100 gm a.i ha^{-1} foliar spray be followed. First spray before imergence of weed (2-3 days after seed sowing) and second spray 45 days after first spray be done in lateritic soil of Konkan region.

5) For lateritic soil of Konkan region in Groundnut and Rice cropping system foliar spray of flucloralin 1.5 kg a.i. ha^{-1} pre emergence weedicide be done for rabi groundnut and for rice oxydiarzon 0.5 kg a.i. ha^{-1} sprayed before weed immergence.

6) For getting higher returns in well drained rice field rice seed be dibbled before mansoon & pre emergence weedicide pritilachlor (50EC) @ 0.5 kg a.i. ha^{-1} be sprayed on wet land.

7) For getting higher return from direct seeded rice during kharif season general package of practices be followed. During rabi season lablabbean be grown without cultivation practices except hand weeding at 20 & 40 days of sowing or spray of pre-emergence weedicide oxydiargil 0.12 kg ha^{-1}.

8) In north Konkan region for direct seeded rice pre-emergence weedicide spray oxyflurphen 300 gm ha^{-1} & post-emergence weedicide 2-4, D 500 gm ha^{-1} be

Table 7. Certified Seed distribution of rice in Maharashtra State (2016)

Sr. No.	Name of Variety	Seed Sold (Q)
1	Jaya	5921
2	Karjat-2	1131
3	Karjat-3	4345
4	Karjat-5	935
5	Karjat-7	3396
6	Masuri	545
7	RTN-24	540
8	RTN-1	619

sprayed or weeding be done at 20 & 40 days of sowing.

9. For kharland of Konkan region 100 kg seed be used for direct seeded kharif rice.

Nutrient management

1. It is recommended to use Urea and Suphala (15:15:15) in 1:1.5 proportion to prepare briquettes by using briquetter machine. Further application of Urea-Suphala briquettes is recommended as alternative to Urea-DAP briquettes to rice crop increase yield and to decrease fertilizer cost.

2. It is recommended to apply Glyricidia mulch @ 1 t ha^{-1} in between two lines along with recommended dose of fertilizers for getting healthy rice seedlings and effective weed control.

3. It is recommended to use Urea-Godawari (14:35:14) in 1.5:1 proportion to prepare briquettes by using briquetter machine. Further application of Urea-Godawari briquettes is recommended as alternative to Urea-Suphala briquettes to rice crop to increase yield and to decrease fertilizer cost.

4. To get higher yield and returns from hybrid rice (Sahyadri) under latertic soil application of Glyricidra 5 t ha^{-1}, N:P:K @ 150:50:75 kg ha^{-1} be followed. Nitrogen split dose be given 50 % at transplanting 25 % in two splits at 1 month duration.

5. To get higher returns in lateritic soil in rice recommended dose of NPK be reduced upto 25% and application of FYM, poultry manure, fish meal, neem cake, organic manure be applied @ 2 t ha^{-1}.

6. In south Konkan coastral zone for getting higher yield & returns from hybrid rice Sahyadri 1 kg m^{-2}. Rice burned husk be applied. Transplanting be done in double row (15x15x25 cm) & application of Glyricidia 5 t ha^{-1} & 56 kg N+ 32 Kg P_2O_5 ha^{-1} and DAP briquettes be done.

7. For getting higher yield and returns from rice & reduction in cost of fertilizers the rice nursery be applied with 0.5 kg m^{-2} rice burned husk. Rice field be applied with 2.5 t ha^{-1}. Glyricidia leaves with Konkan Annapurna briquets 62,500 briquets ha^{-1} instead of urea DAP briquets.

8. For getting high yield and returns from rice, Silicon based Konkan Annapurna briquettes (31:14:6:0.44 N, P, K & Silicon) be used.

Pest Management

1. It is recommended to apply Carbofuran 3G @ 16.5 kg ha^{-1} for management of rice caseworm, when the pest reaches ETL and second application should be given fifteen days after first application, if necessary.

2. One spray of cartap hydochloride 50 SP at the rate of 600 g per 500 lit of water per ha is recommended for the management of rice caseworm. Application should be given, when the pest reaches ETL (two newly infested leaves per hill).

3. Harvesting of rice by "vaibhav sickle" for the management of stem borer

4. A low cost eco friendly integrated approach involving cultivation of stem borer tolerant variety 'Ratna', use of 20 pheromone traps ha^{-1} and need based application of insecticides viz. Carbofuran 16.5 kg ha^{-1} or Cartap hydrochloride 300 g a.i. ha^{-1} appeared to be effective in reducing stem borer infestation.

5. *Scirpophaga incertulus*, *Cnaphalocrosis medinalis* and *Leptocorisa oritorius* are the only species of yellow stem borer, leaf folder and gundhi bug, respectively, existing in the Konkan region of Maharashtra.

6. Yellow stem borer and gundhi bug appeared to be the major pests with their peak population during fourth week of September.

Disease management

1. Three sprays of Tricyclazole (75 Wp) 10 g in 10 L of water (0.1%) or Isoprothiolane (40 EC) 10 ml in 10 L of water (0.1%) are recommended at an interval of 21 days starting from the initiation of blast symptoms for effective management of blast disease of rice.

2. Blue green algae @ 10 kg ha^{-1} was recommended

in paddy field of Konkan region for replacing 25 kg nitrogen.

3. Incorporation of Azolla @ 6 t ha^{-1} was recommended in paddy field of Konkan region to save 30 kg in organic Nitrogen ha^{-1}.

4. For effective management of brown spot of rice spray of Mancozeb @ 0.25% or Zineb @ 0.20 % or Copper Oxycloride @ 0.25% was recommended.

5. For effective management of green algae in paddy field during Rabi season in North Konkan Costal Zone application of 10 kg Azolla ha^{-1} was recommended.

Rice economics

1. Monocropping of Kharif rice was not profitable in Konkan region due to high labour cost, low yields, minimum use of fertilizers, manures, plant protection measures, predominance of small holding, slow acceptance of technological improvement, poor financial conditions and negative attitude of the farmers towards acceptance of crop and crop insurance policies.

2. The rice-oilseeds (groundnut), rice-vegetables, (orka, chilli, tomato, bringal, cucumber, watermelon, onion, little gourd, bitter gourd) cropping systems are more profitable and more employment generating (480-658 days ha^{-1} $year^{-1}$) systems.

3. Greater crop diversity was observed in Thane district of North Konkan. Overall crop intensity of North Konkan (111%) is stable from last two decades.

4. There is considerable potential for crop intensification and diversification in north Konkan provided irrigation facilities and better market infrastructure for disposal of crop production. Location specific strategy of diversification towards high value crops is the necessary task.

5. The technology of drum seeder in rice cultivation must be popularized to overcome the scarcity of labour and increasing wage rates and reducing the cost of cultivation by conducting the large scale demonstrations of drum seeder (direct seeded method) by the department of Agriculture, NGOs and KVKs)

Integrated Farming System

1. In North Konkan Coastal Zone of Maharashtra to get higher yields and economic returns from Kharif rice and Rabi-hot weather rice system, 100 per cent RDF through inorganics be applied to both the crops. However, to improve soil fertility and sustain productivity of Rice under 'Rice – Rice' cropping system, 50% RDF as inorganics (50, 25, 25 kg N, P_2O_5 and K_2O ha^{-1}) be integrated with rest 50 kg N (RDN) in the form of Glyricidia green leaf mannuring during Kharif and 100% RDF as inorganic (120, 50, 50 kg N, P_2O_5 and K_2O ha^{-1}) during Rabi-hot weather season.

2. In north Konkan Coastal Zone of Maharashtra, 'Rice-Brinjal' cropping system is the most profitable one followed by 'Rice-Fodder maize', 'Rice-Cabbage' and 'Rice-Groundnut' systems which may be followed by the farmers depending upon their own needs and local demand for produce in the market.

3. In North Konkan Coastal Zone of Maharashtra 'Rice - Sweet corn' cropping system be fertilized with 100 % recommended NPK as inorganics followed by application of 50 per cent RDF through inorganics alongwith 50 per cent N through FYM to secure maximum yield, net returns and B:C ratio.

4. In North Konkan Coastal Zone, 'Rice-Brinjal' cropping system is found to be most profitable followed by 'Rice-Sweet corn' cropping system which may be grown with minimum tillage by applying 125 per cent RDF to both systems.

5. For yield maximization under rice – rice cropping system of North Konkan Coastal Zone of Maharashtra, hybrid rice be fertilized @ 150:100:150:0.8:10:6 kg N, P_2O_5, K_2O, B, Fe, Zn ha^{-1} during Kharif and @ 150:100:150 kg N, P_2O_5 and K_2O ha^{-1} during Rabi – hot weather season.

Organic rice

1. In North Konkan Coastal Zone of Maharashtra, Rice-Sweet corn system supplied with inorganic sources of nutrients followed by the same system supplied with integrated and organic nutrient management was found to be most profitable. However, to improve soil fertility and sustain productivity, Rice-Groundnut and Rice-Dolichos bean systems also be adopted with organic sources of nutrients.

2. In North Konkan Costal Zone of Maharashtra for rice based organic cropping system, rice as Kharif crop and cucurbits *viz*; red pumpkin and cucumber as Rabi crops be grown. Kharif rice be mannured with $1/3^{rd}$ RDN through FYM, $1/3^{rd}$ RDN through rice straw and $1/3^{rd}$ RDN through Glyricida green leaf manuring, whereas, Rabi cucurbits be mannured as $1/3^{rd}$ RDN through FYM, $1/3^{rd}$ RDN through neem cake and $1/3^{rd}$ RDN through vermicompost, respectively, so as to obtain higher yields and economic returns.

Special Section

Strategies for increasing Rice Production

In a nutshell, the all above recommendations over the time were integrated to formulate a strategy for increasing rice production and productivity in Konkan region. The highlights of this strategy are given below-

•Conservation Agriculture for increasing organic carbon content of soil (minimum tillage, stubble mulch)

•Nursery management

1) Ploughing, harrowing
2) Preparation of raised beds of proper size
3) Incorporation of FYM 100 kg R^{-1}-before sowing, at sowing 3kg suphala 15:15:15 R^{-1} and Urea 1kg R^{-1} 15 DAS
4) Rice husk ash 0.5 to 1 kg m^{-2} on nursery area
5) Sowing seed on raised bed (40-50 kg ha^{-1}).
6) Application of Pre emergence weedicide after sowing seed & on wet bed (Oxadiargil 80 % 0.10 kg ha^{-1} or Butachlor 50 EC 1.5 kg ha^{-1})
7) Hand weeding

•Seed & varieties / hybrids

1) Use foundation / certified seed of recommended varieties Viz., 1) KJT-2 2) KJT-3, 3) KJT-5 4) KJT-7 5) RTN-5 6) KJT-8 7) KJT-9 8) RTN-1 9) RTN-24 10) Sahyadri 11) Sahyadri-4
2) Seed treatment with Thirum 2.5 g kg^{-1}
3) Increase area under hybrid rice upto 25 to 30 % area.
4) Double cropping : Cultivation of pulses, Vegetable during rabi/ summer season.

•Preparation of field: Ploughing, harrowing, puddling

1) Application of FYM 7.5 t ha^{-1}
2) Incorporation of Dhaincha green mannuring (*Sesbania rostrata* variety TSR-1)

•Transplanting: Transplanting at 20 x 15 cm or 15 x 15 cm spacing on leveled field

1) Age of seedling 20-25 days (⅕th of crop duration)
2) Application Urea DAP briquettes
3) Incorporation of Glyricidia leaves 5 t ha^{-1}

•Fertilizer Management:

1) Integrated Nutrient management (INM)
2) 50 kg N, 50 kg P_2O_5, 50 kg K_2O ha^{-1} at transplanting
3) Top dressing Nitrogen 25 N at tillering & 25 kg N at panicle initiation stage

•Weed management:

1) Integrated Weed Management (IWM)
2) Spray pre-emergence weedicide Butachlor 50 EC 1.5 kg ha^{-1}
3) Use of conoweeder 2 times (15 & 30 DAT)
4) Bunds cleaned

•Water Management :

1) Integrated Water Management
2) Maintain water level 2.5 cm for 7 days from transplanting
3) 5 cm upto tillering and milk stage of crop
4) 10 cm from panicle initiation to grain maturity
5) Intermittent drainage of excess water.
6) Drain the water 10 days before harvesting

•Pest & disease Management: Integrated pest management (IPM)

•Recommended package of practices be followed for control of

1) Stem borer
2) Brown plant hopper
3) Blast
4) BLB

•Harvesting, Threshing, Storage :

1) Timely mechanical harvesting.
2) Mechanization
3) Rice Processing for value addition
4) Minimizing the losses during pre and post harvest.
5) Creation of storage facilities at village level.
6) Extension and expansion of technological information through different extension education programmes.
7) Increase in minimum support price.
8) Adopation of Integrated farming system approach.

Technology adoption and yield gap

The primary data on technology adoption and other economic aspects of rice production were collected from 240 randomly selected farmers from Konkan region.

The technology adoption index was estimated as

$$TAI = \frac{1}{k}\left[\frac{AX_1}{RX_1} + \frac{AX_2}{RX_2} + \cdots \frac{AX_k}{RX_k}\right] X\ 100$$

Where,

TAI = Technology adoption index

k = number of technologies

AX_i = Actual use of selected technology

RX_i = Recommended level of selected technology

Based on technology adopted by individual farmer sample farmers were categorised as,

Low adopters = Mean – SD

Medium adopter = Mean – SD to mean + SD

High adopters = Mean + SD

The yield gap for different adopters category was estimated by following methodlogy given by IRRI, Manila, Philippines as -

$$\text{Yield gap I} = Y_p - Y_d$$

$$\text{Yield gap II} = Y_d - Y_a$$

$$\text{Total yield gap} = Y_p - Y_a$$

Where,

Yp = Potential yield realized at research station

Yd = Yield realized at demonstration plots

Ya = Yield realized on sample farms

Distribution of sample farmers

The selected farmers were categorized into three groups as presented in Table 8. The distribution of farmers according to technology adoption index revealed that about 22 per cent farmers were high adoptors, 64 per cent medium and 14 per cent low adoptors. This implied that at overall level there was medium adoption of technology by the sample farmers.

Technology adoption

Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli has released ten production technologies of rice. The technologywise level of adption by sample farmers is given in Table 9. Table 9 revealed that, average adoption index among low, medium and high adoptors was 47.91, 56.00 and 66.78 per cent, with overall average of 57.22 per cent. Among the different technologies of rice production adoption of harvesting technology i.e. harvesting at 90% maturity and use of Vaibhav sickle was the highest (90.67%) followed by tillage operations i.e. ploughing after harvest of previous crop at *Wafsa* condition (83.35%) and seed technology i.e. use of recommended varieties (78.81%). The adoption of technologies like use of FYM/green manuring and Urea briquette was low.

Table 8. Distribution of farmers according to technology adoption.

Sr. No.	Caterory of technology adoption	Range of Adoption Index	No. of farmers (N = 240)	%
1	Low	0 to 48	33	13.75
2	Medium	49 to 62	155	64.58
3	High	Above 63	52	21.67
4	Overall adoption index		57.22	

Yield gap

The results of yield gap analysis are presented in Table 10. The yield gap analysis showed that there is inverse ralation between adoption index and yield gap. It is evident that there is huge potential to increase the yield through technology adoption. The rice farmers need to be motivated to use modern rice production technologies which would add to their farm income.

Economics of rice cultivation

The prifitability of rice production among different categories of adoptors is dipicted in Table 11.

It is evident from Table 5 that, total cost as well as gross income increases with increase in level of adoption. The increase in cost of cultivation on high adoptors farm over low adoptors was 21.68 per cent. However, there was

Table 9. Technologywise level of adoption

Sr. No.	Name of Technology	Low (N=33)	Medium (N=155)	High (N=52)	Overall (N=240)
1.	Tillage operations	62	85	92	83.35
2.	F.Y.M./Green Manure	18	24	58	30.54
3.	Seed Technology	61.78	79.54	87.45	78.81
4.	Weedicide (for nursery)	0	0	0	0.00
5.	Transplanting	66.8	71.33	84.32	73.52
6.	Fertilizers	69.25	74.35	86.46	76.27
7.	Urea Briquette	2.54	6.42	16.82	8.14
8.	Intercultural Operations	46.32	54.48	69.46	56.60
9.	Water level	67.64	74.64	77.52	74.30
10.	Harvesting	84.72	90.24	95.72	90.67
	Average level of adoption	47.91	56.00	66.78	57.22

reduction in per unit cost of production in high adoptor group over low adoptors by 4.94 per cent. The increase in the cost could be attributed to increase in input cost in case of high adoptor group. The benefit cost ratio revealed that rice production is marginaly profitable for high adoptors. The adoption index of high adoptor group was 66.78 per cent. This implies that still there is potential to increase adoption which would ultimately results in further reduction in per unit cost of production and thereby increase in profitability in rice production.

Prices

Price play a vital role in making agriculture remunerative. In recent past, prices of agricultural produce have become more volatile. Prices of agricultural produce are influenced by political factors, international prices, and economic factors. An attempt was made to assess the growth in farm harvest price, minimum support price and actual price realised by farms for the period from 2000-01 to 2011-12.

The Table 12 revealed that at current and constant price, farm harvest price grew at the rate of 9.69 and 3.91 per cent per annum, respectively. During the same period, growth in MSP and actual price realised by farmers at current price was 7.84 and 4.64 per cent per annum. During the same period, growth in MSP was non-significant, whereas, actual price realised by farmers, though non significant showed dealing trend. The foregoing analysis implied that net price relised by farmers for rice did not communsurated with inflation in the economy, which could be the root cause of distress in agriculture in general and rice producers in particular.

Conclusion

To realise the goal of doubling income of farmers in Konkan region, it is necessary to identify sources of growth in income. Increase in the productivity *via* high level of technology adoption would be the significant contributor to output growth and thereby income. This requires emphasis on motivating farmers to adopt modern technologies like seed, fertilizers etc. There is considerable yield gap in rice. This gap could be bridged through technological interventions. The actual price realised by farmers for rice do not commensurate with inflation in the economy, which needs to be adressed through effective policies, and market information.

Success Story

Shri. Vinay Maruti Vekhande a progressive farmer from Vadap village in Karjat taluka of Raigad district. Shri. Vekhande was growing traditional local rice and there after varieties like Ratna, Jaya from that he was getting yield 40 to 45 q ha^{-1}. by adopating varieties released by Univeristy his yield was upto 50-70 q ha^{-1}. and by

Table 10. Yield gap in rice (Figures in parentheses are per cent yield gap to research station yield)

Sr. No.	Particulars	Low		High	Overall
A.	Research station yield		50.00		
B.	Demonstration plot yield		40.00		
C.	Actual yield on sample farms	27.92	31.56	35.74	31.97
	Yield gap – I (A-B)	10.00	10.00	10.00	10.00
	Yield gap – II (B-C)	12.08	8.44	4.26	8.03
	Total yield gap – I (A-C)	22.08	18.44 (36.88)	14.26	18.03 (36.06)

Table 11. Economics of rice production

Sr. No.	Particulars	Low	Medium	High	Overall
1.	Yield q ha^{-1}	27.92	31.56	34.74	31.97
2.	Gross income (₹)	40903.71	46390.76	52898.15	47046.22
3.	Cost C (₹)	42349.35	46916.02	51533.83	47288.63
4.	Per quintal cost of production	1516.81	1486.56	1441.91	1479.16
5.	Net profit	-144.64	-525.26	1364.32	-242.16
6.	B-C ratio	0.97	0.99	1.03	0.99

Table 12. Growth in price

Sr. No.	Particulars	Current price	Constant price (Base year 2004-05)
1.	Farm harvest price	9.69**	3.91**
2.	Minimum support price	7.84*	2.16^{NS}
3.	Actual price realised by farmer	4.64*	-0.88^{NS}

growing Sahyadri hybrids yield reached upto 135 q ha^{-1}. which doubled his income.

He has adopted different techniques developed by Dr. Balasaheb Sawant Konkan Krishi Vidhyapeeth and near about doubled his income. He has followed the following techniques.

1) Used high yielding hybrids developed by University i.e Sahyadri hybrids and received awards for high rice yield.

2) Used Urea briquettes to ensure nutrient supply to the crop for long time during its growth stage.

3) Seed Production of different crop varieties *viz* Karjat-3, Karjat-7, Sahyadri hybrids, Lablab bean (Konkan wal-2) released by DBSKKV from 2012 to 2017 under Gram Bijotpadan

4) Used reaper for harvesting of rice and adopted mechniazation.

Shri Vekhande received appreciation from Dr. Sudhir Goel, Agriculture Commissioner, Maharashtra state and Dr. Vijay Mehta, Vice Chancellor, DBSKKV, Dapoli for seed production efforts.In 2010, he received Raigad district progressive farmer award.

During rabi season, Shri. Vekhande cultivates watermelon (hybrid) on half hectare area and Lablab bean (Konkan wal-2) on one hectare area from which he earns good monetary returns.

Table 13. Production, productivity and income of Shri Vekhande prior and after adoption of DBSKKV interventions for rice.

Year	Yield (q ha^{-1})	Awards
2003-04	120	First prize in Karjat Taluka
2004-05	130	First prize in Raigad District
2005-06	135	First prize in Maharashtra State

Way forward

The population is increasing day by day and land is shrinking. Therefore, rice production has to increase for maintaining food security. For rice production major constraint is labour problem at critical stages of crop growth. Therefore, mechanization will solve the problem. Reorienting research and technology development will meet emerging challenges. The future priorities are development of high value nutritionally rich varieties, tolerant to submergence, low light intensity, salt tolerant and varieties suitable for processing industry. The technology for doubling farmers income will be developed.

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Table 14. Production, productivity and income of Shri Vekhande prior and after adoption of DBSKKV interventions for rice.

Varieties	Prior			Present		
	Local	Ratna	Jaya	Karjat-3	Karjat-7	Sahyadri
Production (q)	93	120	135	150	156	240
Productivity (q ha^{-1})	31	40	45	50	52	Potential: 120 Average: 80
Income ha^{-1}	46,500	60,000	67,500	75,000	78,000	1,20,000

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