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Milling characteristics of some popular rice varieties of Tamil Nadu and Andhra Pradesh

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Abstract: Thirty two paddy varieties of Tamil Nadu and Andhra Pradesh were studied for their milling performance. Among them eight promising varieties known for raw milling were grown under identical conditions at Thanjavur. The crop was harvested at right moisture, dried under low intensity of sunlight and milled at laboratory and commercial level after storing 3 and 6 months. Among the high yielding varieties, ADT 39, MTU 2069, MTU 2077, MTU 7029 and White Ponni were found suitable for raw milling, having less than 5% milling breakage. The highest milling yield was observed in ADT 39. The two traditional varieties Kitchili samba and Jeeraga samba are the best regarding their milling resistance. The widely grown White Ponni of Tamil Nadu even at 15.4% harvest moisture has shown better suncheck resistance and has very good cooking performance. Though the milling yield was high in all the MTU varieties, the cooking performance was better for the variety MTU 7029. *(Key words: Traditional varieties, High yielding varieties, Milling yield, Cooking quality).*

Husk content of the variety, the degree of milling and grain breakage determine the yield of rice from paddy. Husk content is genetically controlled and degree of milling depends on customers preference but the extent of breakage is unpredictable. Eventhough, the crack development, varietal characteristics and milling machinery are some of the important factors that affect milling breakage, the causes of breakage are not still well understood (Bhattacharya 1980). Other factors influencing head rice recovery include shape, size, appearance of grains and environmental factors (Khush *et al.* 1979).

Some of the prevailing varieties may have the potential to give higher yield with lesser milling breakage. However, experimental evidence on these aspects are generally lacking. Hence, this study was conducted with the view to assess the milling performance of some prevailing paddy varieties of Tamil Nadu and Andhra Pradesh.

Materials and Methods

Seeds of thirty two paddy varieties were collected from Agricultural Research Stations, Maruteru and Nellore, Andhra Pradesh, Soil and Water Management Research Institute, Thanjavur, Tamil Nadu and private farmers of Andhra Pradesh and Tamil Nadu. These samples were screened of varieties and tested at laboratory level. Based on the initial milling results and farmer's opinion, eight varieties *viz.* ADT 39, IR 64, White Ponni, Jeeraga Samba, MTU 2069 (Chaitanya), MTU 2077 (Krishnaveni), MTU 7029 (Swarna) and Kitchili samba were selected for the study and grown under identical conditions, during Samba season (September to January) at Soil and Water Management Research Institute, Thanjavur, Tamil Nadu. Harvested at higher moisture of 19 - 22%, threshed without field drying (*Arikkaichal*), dried under less intensity of sunlight and stored with proper care. The moisture content, sunchecks were assessed soon after harvest, before storage and after 3 and 6 months storage prior to millings. The paddy crack detector was used to assess the cracks. The stored paddy of these varieties were milled after 3 and 6 months both at laboratory and commercial level.

Physical parameters like husk content, 1000 grain weight, length, breadth, thickness, surface area of paddy / brown rice and hardness were assessed. Length (L) and breadth (B) of 10 grains at a time were measured using grooved wooden board thickness using a dial caliper to an accuracy of 1mm and 0.01mm respectively. The surface area was calculated as given below (Bhattacharya *et al.*, 1982 b) :

$$S = \frac{3}{4} \times \frac{22}{7} \times L\sqrt{(B^2 + T^2)/2} \times N \text{ mm}^2/\text{g},$$

where S - surface area, L, B, T - length, breadth, thickness of paddy or brown rice and N - Number of grains per gram. Hardness was measured using Kiya hardness tester and expressed as (kg/mm^2). The varieties were classified according to Ramiah's Committee classification (Anonymous 1968) and as per uniform specification. The whiteness and transparency of the brown rice and polished rice were measured in Satake milling meter using their standard plates white and brown as reference and expressed as percentage.

For laboratory milling, initially paddy was cleaned in Carter Day Dockage Tester, shelled in Satake Grain Testing Mill (type THU) and milled in McGill miller No. 2. The samples were milled to about 6% polish in duplicate and bran

Table 1. Milling performance of different paddy varieties - laboratory milling

Variety	Husk content (%)	Polished rice yield (%)	Polish (%)	Milling breakage (%)	HR yield (%)
IR 50	19.70	76.04	4.96	7.08	70.66
IR 64	21.35	74.20	5.52	10.37	66.50
IR 72	21.38	73.94	5.80	31.47	50.68
ADT 36	21.00	73.62	6.56	30.40	51.23
ADT 37	19.03	75.71	6.20	6.52	70.77
ADT 38	18.99	76.33	5.70	2.80	74.19
ADT 39	19.95	75.16	5.90	30.37	52.32
ADT 41	23.97	70.99	6.42	24.22	53.79
ADT 42	20.02	75.12	5.87	15.32	63.61
ASD 18	22.57	72.45	6.24	66.80	23.76
White Ponni	22.36	73.49	5.17	23.12	56.50
Jeeraga Samba	21.96	72.96	6.04	3.65	70.30
IR 64*	20.51	74.44	5.78	33.4	49.58
MTU 1001	21.99	72.89	6.02	42.7	41.76
MTU 2069	20.94	73.62	6.37	16.85	61.21
MTU 2077	19.99	75.12	5.60	13.30	65.13
MTU 7029	19.87	75.00	5.69	8.50	68.72
Kerala Basmati	22.07	72.47	6.54	21.35	57.00
Kitchili Samba	22.67	72.36	5.86	2.00	70.91
NLR 28523	20.62	73.96	6.13	50.00	36.98
NLR 27999	21.05	73.83	5.72	66.40	24.81
Bulk H9	20.42	75.16	5.05	79.27	15.58
BCP 2	20.45	74.54	5.66	76.05	17.85
BCP 3	21.44	72.66	6.84	12.47	63.60
BCP 4	21.35	73.41	6.26	91.15	6.50
BCP 5	21.86	73.42	5.50	90.20	7.19
BCP 6	20.99	74.96	4.77	70.30	22.26
IET 1444	19.70	75.63	5.46	31.90	51.50
NLR 13969	20.58	74.50	5.85	39.25	45.26
NLR 33358	20.10	74.54	6.19	14.75	63.54
NLR 30491	24.22	70.37	6.28	17.60	57.98
Potti Nallavari	22.11	72.76	6.17	51.52	34.12

HR - Head Rice yield; *Source of collection, A.P.

was analysed for its oil content. Before milling, the moisture content of paddy, sunchecks and hardness were assessed.

Commercial milling trials were performed in Satake mini mill of 300 kg / h capacity. Three hundred kilogram of paddy was cleaned to remove chaff, dust and immatures by aspiration. The cleaned paddy was shelled and the entire brown rice without any paddy was milled in 2 stages, initially by removing 2- 4% and the remaining in second stage, so as to obtain about 7-8% total polish.

The Equilibrated moisture content on soaking at room temperature for 23 hours (EMC-S) was assessed for polished rice. (Indudhara Swamy *et al.*, 1971). Elongation during cooking (Juliano and Perez 1984), optimum cooking time (OT) (Ranghino, 1966), alkali score (Bhattacharya *et al.*, 1972) were also assessed for the polished rice. The gelatinization temperature (GT) was derived from the regression equation Y = 74.54 - 1.40 x (Alkali score) (Bhattacharya *et al.* 1982a).

Results and Discussion

Screening of varieties by laboratory milling test

The 32 varieties screened showed that the percentage of husk content ranged from 19.0 (ADT 38) to 24.2% (NLR 30491). The maximum

Table 2. Moisture content and suncheck percent in paddy varieties at harvest and during storage

Variety	At harvest		During storage period					
	Moisture content (%)	Sunchecks (%)	3 months		6 months		18 months	
			M.C. (%)	S.C. (%)	M.C. (%)	S.C. (%)	M.C. (%)	S.C. (%)
ADT 39	19.1	1.3	12.6	2.7	12.1	2.7	11.5	2.7
IR 64	23.0	0.7	12.3	1.0	12.2	1.3	11.6	1.3
MTU 2069	19.0	Nil	11.8	0.3	11.8	0.3	11.9	1.0
MTU 2077	22.2	Nil	12.3	0.3	11.6	0.3	11.7	0.3
MTU 7029	19.9	Nil	12.0	0.7	11.5	0.7	11.8	0.3
White Ponni	15.4	0.3	12.1	1.0	11.9	1.7	11.8	2.7
Kitchili Samba	22.7	0.3	12.0	0.3	11.9	2.0	11.3	2.0
Jeeraga Samba	21.0	0.7	12.0	1.0	11.7	1.3	11.5	1.0

M.C. - Moisture Content; S.C. - Suncheck

and minimum milling yield was 76.3 and 70.4% for the above varieties. The milling breakage of Kitchili samba, ADT 38 and Jeeraga samba was 2.0, 2.8 and 3.6% respectively indicating the maximum resistance to milling (Table 1).

Based on the results of screening test, farmer's and miller's opinion 8 varieties were selected and grown under identical conditions. The paddy obtained was indicated as experimental paddy.

Processing conditions and physical parameters of experimental paddy

The moisture content of the varieties tested, ranged from 19 to 23% at harvest and White ponni had 15.4% moisture. Including White ponni all the varieties had less than 1% suncheck. In a systematic screening of varieties for crack resistance and susceptibility Srinivas *et al.* (1977) found that under same agronomical and harvesting conditions rice varieties varied in the extent of grain cracking from 5.5 to 73% at 18% average grain moisture. Srinivas *et al.* (1981) reported that 7.2, 10.0 and 37% of sunchecks in FT 19, FT 35 and Vani at about 16% harvest moisture of paddy. Kunze and Prasad (1978) observed some varietal difference in susceptibility to cracking. In this study, the popular Tamil Nadu variety, White Ponni showed lesser sunchecks even at the harvest moisture of 15.4%. Also it is noteworthy that all the varieties have not showed any additional cracks during storage (Table 2).

The physical characteristics of paddy and rice (Table 3) showed that the husk content varied between 19.1 to 22.9%. It was observed that the two traditional varieties Kitchili samba and Jeeraga samba have higher husk content. After analyzing 151 paddy varieties it was reported that the husk content was less in coarse (20.8%), compared to that of fine (21.9%) and super fine (22.1%) varieties (Sulochana and Pillaiyar 1994). The fine variety Jeeraga samba had minimum length breadth ratio (L:B) of 2.44 and the long slender IR 64 the maximum of 3.43. The tiny kernels of Jeeraga samba had the maximum surface area (2113.5 mm^2) while MTU 2069 and IR 64 had the minimum around 1635 mm2 . The hardness of the grains varied from 11.43 (Jeeraga samba) to 18.82 kg/mm^2 (Kitchili samba) after 3 months storage. The brown rice colour of all the varieties was found to be dull white and ranged from 17.6 (ADT 39) to 22.4% (Kitchili samba). The whiteness of milled rice varied from 29.7 to 34.3%.

The bran oil content (average of 6 samples of lab milling) of Jeeraga samba was the least 20.4% followed by IR 64. The maximum oil was observed in ADT 39 (26.9%) followed by MTU 7029 with 26.7% (Table 3).

Laboratory milling performance of 3 and 6 months stored experimental paddy

The brown rice and polished rice yield was maximum in ADT 39 *ie.* 80.8 and 75.7% respectively after 3 months. The milling breakage (MB) ranged from 0.2 (Jeeraga samba) to 5.5% (IR 64). Milling after 6 months reduced the milling breakage and it ranged from 1.0 (ADT 39) to 3.3% (White Ponni). The reduction in milling breakage was well pronounced in IR 64 (from 5.5 to 2.0%) than in other varieties and it was statistically significant.

Table 3. Physicochemical characteristics of some paddy varieties from Tamil Nadu and Andhra Pradesh

Variety	Husk content(%)	1000 grain weight (g)		Length : Breadth		Surface area (mm^2/g)		Colour (%)		Classification as per		Bran oil content
		Paddy	Br.rice	Paddy	Br.rice	Paddy	Br.rice	Br. rice	Milled rice	Ramaiah's committee	Classification	
ADT 39	19.1	20.8	16.8	3.10	2.77	2075.87	1685.85	17.6	30.9	LB	F	26.9
IR 64	19.8	25.3	20.3	3.90	3.43	1958.23	1638.48	19.1	31.6	LS	SF	22.9
MTU 2069	21.5	22.2	17.5	3.20	2.73	2049.42	1634.87	22.3	34.3	LB	F	25.2
MTU 2077	20.1	20.9	16.7	2.97	2.58	2023.32	1707.36	19.9	31.7	MS	F	23.4
MTU 7029	20.7	19.9	15.8	2.90	2.53	2114.89	1756.77	18.5	30.1	MS	F	26.7
White Ponni	21.0	17.0	13.5	3.36	2.98	2247.07	1824.15	22.0	32.1	MS	F	23.7
Kitchili samba	22.9	18.4	14.2	3.25	2.92	2128.30	1811.04	22.4	32.1	MS	F	24.8
Jeeraga samba	21.6	10.0	7.9	2.77	2.44	2614.38	2113.50	18.9	29.7	MS	F	20.4

Commercial milling trials, after 3 months storage of experimental paddy

The variety ADT 39 with minimum husk content reflected in higher brown rice and milled rice yield of 79.8 and 72.3% respectively. In this variety 4.7% of brokens were observed. The two traditional varieties Kitchili samba and Jeeraga samba with highest husk content gave the lowest brown rice (75.1 and 76.2%) and polished rice yield (69.1 and 69.5%) respectively. But, the least breakage of less than 2% was observed in these varieties and this shows that these varieties acquire milling resistance during storage at an earlier stage (Table 4).

The White Ponni harvested at 15.4% moisture gave 77.3% of brown rice and 69.7% of milled rice yield with 5.8% breakage. All the 3 Maruteru (MTU) varieties performed well giving 3.8 to 5.5% brokens (Table 4) .

The long slender IR 64 inspite of its low husk content next to ADT 39 gave the minimum of 68.8% milling yield, due to the higher breakage upto 15.9%. Inspite of high harvest moisture of 23% and low suncheck percentage (0.7%), the higher breakage in this variety is probably due to the slenderness of this variety. Certain varieties are said to break because, their grains are either soft or chalky or long and slender (Bhattacharya 1980). According to Mahadevappa and Nandisha (1987) varieties with superior grain quality have higher breakage in milling because they are slender. However, it should be noted that the grain quality of IR 64 is not superior.

Comparison of commercial milling of experimental paddy stored for 3 and 6 months

Milling after 6 months did not increase its brown rice or polished rice yield significantly, though a trend of increase was observed (Table 4). But the breakage reduced significantly in 5 varieties namely, ADT 39, IR 64, MTU 2077, MTU 7029 and White Ponni. The reduction in breakage ranged from 1.4 (MTU 7029) to 5.5% (IR 64). This confirms that breakage in a sample decreases as it ages (Bhattacharya 1980; Anthoni Raj and Singaravadivel 1987). The two traditional varieties and MTU 2069 did not show any significant difference in milling breakage, though a trend of reduction of breakage is noted. Also this confirm the earlier hardening of grains, so as to withstand milling pressure at an earlier storage period.

Comparison of milling breakage between screening test paddy and lab milling of experimental paddy

Table 4. Milling characteristics of different paddy varieties - commercial milling (P x V Tables)

Variety (V)	Periods (P)		V-Mean	Diff	Comparison-2-P V means; -2-P means	
	3 Months	6 Months		S.E.D.	LSD(5%)	LSD(1%)
Brown rice yield (%)						
ADT 39	79.75 a	80.32 a	80.04 a	-0.57 ns		
IR 64	77.74 c	79.84 a	78.79 b	-2.10 **		
MTU 2069	79.10 ab	78.56 bc	78.83 b	0.54 ns		
MTU 2077	78.42 bc	79.43 ab	78.93 b	-0.01 ns	0.52	0.11 1.54
MTU 7029	77.73 c	77.99 c	77.86 c	-.0.26 ns	0.18	0.39 0.54
W. Ponni	77.29 cd	78.00 c	77.64 cd	-0.71 ns		
K. samba	75.11 e	75.51 d	75.31 e	-0.40 ns		
J. Samba	76.24 d	77.66 c	76.95 d	-1.42 *		
P-Mean	77.67	78.41	78.04	-0.74 **		
Milling yield (%)						
ADT 39	72.29 a	73.45 a	72.87	-1.16*		
IR 64	68.84 d	71.70 bc	70.27	-2.86 **		
MTU 2069	71.76 ab	71.14 cd	71.45	0.62 ns		
MTU 2077	71.37 ab	72.33 b	71.85	-0.96 ns		
MTU 7029	70.25 c	70.23 de	70.24	0.02 ns	0.46	0.98 1.35
W. Ponni	69.68 cd	71.21 cd	70.44	-1.52 **		
K. samba	69.10 d	68.71 f	68.91	0.39 ns		
J. Samba	69.46 cd	69.83 e	69.65	-0.37 ns		
P-Mean	70.34	71.07	70.71	-0.73		
Polish (%)						
ADT 39	8.0 bc	7.79 b	7.90	0.21 ns		
IR 64	8.99 a	8.07 ab	8.53	0.92 ns		
MTU 2069	7.11 d	8.21 ab	7.66	-1.10 *		
MTU 2077	7.15 d	7.99 b	7.57	-0.84 ns	0.45	0.96 1.33
MTU 7029	7.67 cd	8.53 ab	8.10	-0.86 ns		
W. Ponni	8.35 ab	7.79 b	8.07	0.56 ns		
K. samba	7.11 d	7.82 b	7.47	-0.71		
J. Samba	8.00 bc	9.11 a	8.55	-1.11 *		
P-Mean	7.80	8.16	7.98	-0.37		
Total milling breakage (%)						
ADT 39	4.68 cd	2.48 c	3.58	2.20 **		
IR 64	15.88 a	10.43 a	13.15	5.45 **		
MTU 2069	3.93 d	3.83 b	3.88	0.11 ns		
MTU 2077	3.82 d	1.55 c	2.68	2.27 **		
MTU 7029	5.49 bc	4.10 b	4.79	1.39 **	0.43	0.92 1.27
W. Ponni	5.83 b	4.29 b	5.06	1.54 **		
K. samba	1.96 e	1.88 c	1.92	0.08 ns		
J. Samba	1.93 e	1.79 c	1.86	0.14 ns		
P-Mean	5.44	3.79	4.61	1.64		

** Significant at 1% level, ns = not significant

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

The milling breakage of 3 months stored experimental paddy was compared with screening test paddy *ie.* milling of paddy samples received from various sources with unknown pre and post harvest conditions of paddy. Among the 8 varieties compared all the high yielding varieties showed significant difference in milling breakage, varying from 6.8 to 28.2% (Table 5). It is interesting to note that even the random samples of the traditional varieties, Kitchili samba and Jeeraga samba have exhibited less breakage and significant difference was not noted between these two millings. This shows that these varieties are inherently resistant to breakage, which indirectly reflects its resistance to field checks and milling pressure.

As per uniform specification for Grade 'A' and common raw rice the limit of allowable brokens is 25%. The above varieties studied exhibited less than 5% milling breakage except IR 64 which had 13.1% (average of 2 periods). Hence, all the above varieties tested can be taken up as suitable for raw milling. According to "The trial millings for FCI " - Report 1994, the variety MTU 7029 tested in large scale at three rice mills owned by Food Corporation of India at Andhra Pradesh showed 1.5% and 4.4% nooks only in two trials and 10.5% of brokens in another trial, (Anonymous, 1994). This variety has also shown good milling performance at Tamil Nadu state. Among the 3 Maruteru (MTU) varieties MTU 7029 performed well giving elongation ratio of 1.8 and elongation index of 1.35 on cooking.

Cooking quality parameters of the varieties milled (Table 6) shows that the equilibrium moisture content on soaking of polished rice ranged from 36.2 (MTU 7029) to 46.44% (Jeeraga samba). The elongation ratio ranged from 1.63 (MTU 2077) to 2.05 (Jeeraga samba). The elongation index ranged from 1.1 (IR 64) to 1.58 (Jeeraga samba).

Table 5. A comparison of milling breakage between commercial and experimental paddy

Variety	Commercial paddy	Experimental paddy	V mean	Difference
ADT 39	30.38a	2.15a	16.26	-28.23**
IR 64	33.43a	5.52a	19.47	-27.91**
MTU 2069	16.85a	1.70a	9.27	-15.16**
MTU 2077	13.30c	2.48a	7.89	-10.83**
MTU 7029	8.48d	1.70a	5.09	-6.77**
White Ponni	23.13b	2.79a	12.96	-20.34**
Kitchili samba	1.95e	2.03a	1.99	0.07ns
Jeeraga Samba	3.65e	0.22a	1.94	-3.43ns
P. mean	16.39	2.32	9.36	-14.07

* Significant at 5% level; ** Significant at 1% level; ns-not significant
In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Table 6. Quality characteristics of rice from Tamil Nadu and Andhra Pradesh

Variety	Hardness (kg/mm^2)		EMC-S (%)		Elongation		OT (min)	GT (°C)
ADT 39	17.39	17.10	38.98	37.98	1.71	1.18	19.0	69.4
IR 64	18.16	18.90	38.44	37.85	1.64	1.10	19.5	68.6
MTU 2069	17.16	19.76	38.58	36.42	1.69	1.21	18.5	68.6
MTU 2077	14.69	15.73	36.97	36.23	1.63	1.16	20.0	70.3
MTU 7029	18.57	15.94	36.25	35.24	1.80	1.35	18.5	70.7
W. Ponni	18.49	18.65	39.08	36.85	2.01	1.49	15.5	68.6
K. samba	18.82	19.12	37.72	35.75	1.95	1.44	17.0	68.9
J. samba	11.43	10.37	46.64	38.93	2.05	1.58	14.0	69.6

Among the varieties studied, IR 64 was inferior in cooking quality. Similarly, though IR 50 is a long slender variety, it exhibited minimum elongation index of 0.89, among the twenty five varieties studied (Pillaiyar 1988). Hence, not all slender varieties have superior grain quality. Chikkalingaiah *et al.* (1999) after studying 24 scented varieties, recommended that amylose content, milling recovery, kernel elongation ratio, total number of tillers and number of effective tillers as important selection criteria for genetic variability of plant and quality traits. Considering the elongation index Jeeraga samba followed by White ponni and Kitchili samba are superior in rice quality. It is a well known fact that Basmati type of grains elongate more giving 2.16 and 1.65 (Basmati 370) elongation ratio and index (Juliano and Perez 1984). Similarly Jeeraga samba and White ponni have given comparatively more elongation when stored for longer period (Table 6).

The optimum cooking time of the varieties tested ranged between 14 (Jeeraga samba) to 20 min (MTU 2077). According to Bhattacharya and Sowbhagya (1972), cooking time is not a sensitive test of rice quality as it is directly related with the thickness and more so with the surface area of the rice. Accordingly, Jeeraga samba with maximum surface area was cooked in the minimum time of 14 min.

Conclusions

All the six high yielding varieties collected from Tamil Nadu and Andhra Pradesh are suitable for raw milling exhibiting less than 5% breakage. Only IR 64 has yielded 15 and 10% breakage after 3 and 6 months milling which can not be considered as high breakage as it is a long slender variety. But inspite of its slenderness this variety has poor cooking characteristics. The variety ADT 39 has high milling yield. Both the traditional varieties Kitchili samba and Jeeraga samba are the best varieties regarding its milling breakage resistance. The widely grown White ponni of Tamil Nadu even at 15.4% harvest moisture has shown better suncheck resistance and has very good cooking performance. The variety MTU 7029 performed well both in Andhra Pradesh and Tamil Nadu. It has good cooking quality too. Hence, the varieties *viz.* Kitchili samba, Jeeraga samba, White ponni and MTU 7029 can be taken as good breeding materials for the trait of milling and cooking performance.

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Techno – economics of watershed management - A case study

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Abstract: The Vagpura watershed in Jhadole Tehsil of Udaipur District, Rajasthan was undertaken for preparing an economical design plan of conservation measures and estimating benefit cost ratio. For the proposed watershed, location and site specific soil and water conservation measures like contour bunding, stone wall terracing, contour furrows, pasture development, grass waterway, diversion channel, earthen embankment reservoir for water harvesting are recommended. Cost analysis of the proposed measures resulted that; total cost for development of watershed comes out to be Rs. 3469 per hectare. Benefit cost ratio analysed by economical and financial evaluation methods was found to be 1.6:1 and 1.38:1 respectively. *(Key words: Water shed, Conservation measures, Water harvesting)*

Rajasthan State is the second largest state of Indian union covering 34.3 million ha of land and forest area occupies only about 9 per cent of geographical area of the State. The Aravelly system as a whole covers 32.69 per cent of total area of the State. About 8 milloin ha of hilly tracts bear some kinds of forest growth which now have become most degraded due to over exploitation, and incident of grazing and shifting cultivation (Sharma, 1990). Patil and Sahane (1969) and Gawand *et al.* (1974) have observed appreciable increment in ground water recharge from contour bunded fields. To ensure an ecological balance and economic security, an integrated approach of watershed basis is considered essential. Different techniques like crop production, soil and water conservation, water management, pasture development, afforestation etc. therefore need to be simultaneously adopted on watershed basis so that the efficiency of use of natural resources as well as applied inputs become high (Pandey and Kiran 1991). Singh *et. al.* (1992) have evaluated the potential of severely eroded 'Thakarda' watershed in terms of conservation and development resources and increase in productivity through watershed management programme. They reported that the yield of wheat and maize increased from 7.5 q ha^{-1} to 21.6 q ha^{-1} and 5.0 q ha^{-1} to 14.35 q ha^{-1} respectively. Watershed development treatments are economically viable in south Rajasthan as the investment made in the project received in four years from increased crop production (Prasad *et al.* 1997).

The Vagpura watershed covering an area of 179.60 ha was selected in Jhadol Tehsil of Udaipur district to prepare a development plan and to conduct benefit cost ratio analysis on watershed basis. Contour Bunding (CB) has been