The Pharma Innovation Journal 2023; 12(12): 3771-3779

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(12): 3771-3779

www.thepharmajournal.com
Received: 04-09-2023
Accepted: 10-11-2023

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Studies of biochemical analysis of rice (*Oryza sativa*) genotypes under *kharif* and different sowing windows during *rabi* season in Konkan

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Abstract
The field experiment was laid out with 40 early duration rice germplasms in Split Plot Design with three replications during *kharif*-2020, *kharif*-2021, *rabi*-20-21and *rabi*-21-22 with the objective to biochemical characterization response of 40 early duration rice genotypes under *kharif* and different sowing windows during *rabi* season in Konkan. The results revealed that the rice crop sown during *rabi* season, S_4 (the 50th MW) date of sowing recorded significantly maximum carbohydrate content (82.18%) as compared to crop sown during S_2 (48th MW) and S_3 (50th MW). Rice variety V_7 i.e. Sahyadri-4 recorded significantly maximum carbohydrate content (83.23%). The rice crop sown during *rabi* season, S_4 (the 52th MW) date of sowing recorded significantly maximum protein content (6.27%) as compared to crop sown during S_2 (48th MW) and S_3 (50th MW). Rice genotype V_{28} i.e. IRRI-53 recorded significantly maximum protein content (7.09%) which was at par with V_{35} i.e. Amb pandhari (7.04%). The rice crop sown during *rabi* season, S_4 (the 52th MW) date of sowing recorded significantly maximum nitrate reductase activity 2.131 µmolg^{-1} and 2.469 µmolg^{-1} at tillering and flowering stage. S_1– *kharif* season (24th MW) produced significantly maximum amylose content (22.46%) as compared to other sowing dates of *rabi* season (8th MW, 50th MW,52th MW) S_1– *kharif* season (24th MW) produced significantly maximum iron content (8.68ppm) as compared to other sowing dates of *rabi* season (48th MW, 50th MW, 52th MW). S_1–*kharif* season (24th MW) produced significantly maximum iron content (13.1ppm) as compared to other sowing dates of *rabi* season (48th MW, 50th MW, 52th MW).

Keywords: Rice genotypes, biochemical characters, *kharif* and different sowing window in *rabi* season

Introduction
Rice belongs to genus *Oryza*, of the family Poceace and is widely cultivated crop (FAO, 2000; Syed and Khaliq, 2008) [11-12]. Genus *Oryza* contains approximately 24 species, of which 21 are wild type and two; *O. sativa* and O. *glaberrima* are cultivated world-wide (Vaughan, 2003) [32]. It is the most important food crop worldwide, representing the staple food and more than half of world population depends on its consumption and income generation (Bucheyeki *et al.*, 2011) [6]. Rice believed to have originated in Asia. Ancient records showed that Greek introduced rice to India around 326 B.C. then after, it spread across Europe for the next 2000 years. It was brought to the new world (South and North *Glaberrima*, *Oryza sativa* is native to tropical and subtropical Southern Asia that there are three groups of *Oryza* cultivar cultivars *viz; Japonica*, *Javanica* and *Indica*.). Rice is being cultivated in 117 countries across the world in every continent except Antarctica and hence called as "global grain".
Rice (*Oryza sativa* L., 2n=24) is important cereal crop in India and staple food of more than 60% of Indian population. Total production of rice estimated at record 130.84 million tonnes (Anonymous, 2023) [4]. Rice is the second important crop of Maharashtra and is grown over an area of 14.65 lakh hectares with an annual rice production of about 32.76 lakh tonnes. 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 34 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 tha^{-1} to $4.35tha^{-1}$ wwwcal.researchgate.net Technological interventions boon for rice production in konkan region, 2020).

It is believed that the second 'Green revolution' will more heavily be driven by the development of cultivars with better yielding ability. Thus, increasing the yielding ability is important. (Khush and Peng, 1996) [21]. It is desirable to study yield and yield contributing traits like number of effective tillers per plant, number of grains per panicle, 1000 grain weight, days to 50% flowering, days to maturity and plant height which have shown positive association with grain yield.

The major rice districts in Maharashtra are Thane, Raigad, Ratnagiri, Sindhudurg and Palghar along with west coast and Bhandara, Gondiia, Gadchiroli and Chandrapur in the eastern part of state, Konkan region occupies an area of about 3.69 lakh hectare under rice with production of about 12.94 lakh tonnes and productivity around 2.93 tonnes ha^{-1}.

Rice is the main cereal crop in Konkan and it is cultivated in *kharif* as well as *rabi* season. During *kharif* season, the sowing of rice in the month of June and should be harvested in the month November, therefore the pre cultivation operations should be late in *rabi* season means the sowing of rice will be in the month of December. Most of area of Raigad and Ratnagiri, Sindhudurg water of canal will be provided in the month of December and harvest the crop in the end of May. That time lot of loss of crop due to pre monsoon rainfalls. Therefore, it is very important that harvesting be at end of April or the first week of May. Dr BSKKV, Dapoli released of high yielding varieties for the *kharif* and *rabi* season. The sowing time of the rice crop is important for three major reasons. Firstly, it ensures that vegetative growth occurs during a period of satisfactory temperatures and total sunshine hours. Secondly, the optimum sowing time for each cultivar ensures the cold sensitive stage occurs when the minimum night temperatures are historically the warmest. Thirdly, sowing on time guarantees that grain filling occurs when milder autumn temperatures are more likely, hence good grain quality is achieved. Results from different studies revealed that the maximum yield potential of a rice crop is usually achieved when the crop is exposed to the most appropriate temperature range, which can be controlled by sowing at the proper time.

In the present study for the summer rice, the sowing of rice variety is in the 48th metrological week (1st December), 50th metrological week (15th Dec) and 52th metrological week (30th, Dec) and keeping view to study biochemical attributes related to growth and yield of 40 early duration rice genotypes as influenced by different sowing window during *rabi* season in Konkan.

Materials and Methods

The experiment was carried out at Regional Agricultural Research Station, Karjat, Dist. Raigad (MS) during *kharif-2020* and *kharif-2021* as well as *rabi-2020-21* and *rabi -2021-22*. It is situated at 18°91'67" North latitude and 73°33' East longitude with an altitude of 194 meters (636 ft) above the mean sea level with warm and humid conditions throughout the year. The mean annual precipitation is 3500 mm, which is generally received during the month from June to November at the location. The experiment was laid out with 40 early duration rice germplasms in Split Plot Design with three replications during *kharif-2020* and *kharif-2021* as well as *rabi 2020-21* and *rabi 2021-22* with different sowing windows.

The experiment comprised of forty genotypes of rice, laid out in Spilt Plot Design with three replications. The seeds were sown on 2nd week of June 2020 and 2021during *kharif* season and 1st, 2nd and 3rd sowing on 1stDecember, 15th December and 30th December during *rabi* season on raised beds. After 25 days, seedlings were transplanted with spacing of 15 cm between row and 15 cm between plants in rows with plot size 2.10 m x 0.75 m. for each variety in the plot. The field experiment was conducted at normal fertility level on lateritic soil. Fertilizers applications were done @ 100 kg N, 50 kg P_20_5 and 50 kg K_20 per hectare.

Results

Data on carbohydrate content, protein content, nitrate reductase activity, amylose content, iron content and zinc content for rice genotypes are presented in Table -1 to Table 7.

1. Carbohydrate content

In the present investigation, significant differences were observed within rice genotypes for grain carbohydrate content. Crop sown during S_1–*kharif* season (24thMW) produced significantly minimum carbohydrate content (78.68%) as compared to other sowing dates of *rabi* season (48th MW, 50th MW,52th MW).The rice crop sown during *rabi* season,S_4 (the 50th MW) date of sowing recorded significantly maximum carbohydrate content (82.18%) as compared to crop sown during S_2 (48th MW) and S_3 (50th MW). Rice variety V_7 i.e. Sahyadri-4 recorded significantly maximum carbohydrate content (83.23%).The rice genotype Ratnagiri -24 recorded significantly minimum carbohydrate content (73.89%) which was followed by V_{11} i.e.Ratnagiri-6 (78.22%).In case of *rabi* season S_4V_4 i.e. crop sown in S_4 date of sowing (52th MW) with Karjat-7 was recorded significantly higher carbohydrate content (85.48%) which was superior with all treatment combinations during pooled mean over others.However,,S_2V_{33} with rice genotype Narmada recorded significantly minimum carbohydrate content (77.08%) which was followed by S_2V_{35}(78.47%).

Varietal difference for carbohydrate content was also reported by Asaduzzaman *et al*. (2013) [5] determined the starch content of different aromatic rice varied between 63.193 to 72.60/100 g. Chingakham *et al.* (2016) [8] observed that carbohydrate content of the black rice varieties were more than 70 percent. Therefore, the black rice varieties are good source of carbohydrate. Gimhavanekar *et al.* (2020) [16] observed that rice varieties *viz* ly, Karjat-3 and Karjat-7 recorded 73.23% and 74.06% carbohydrate respectively.

2. Protein (%)

Despite the negative influence on the texture of cooked rice, high protein content rice is considered to be nutritious in grains and thus rice grains with high protein content possess high nutritive value while rice cultivars with low protein content could prove to have desired cooking qualities.

In the present investigation, crop sown during S_1–*kharif* season (24th MW) produced significantly minimum protein content (5.75%) as compared to other sowing dates of *rabi* season (48th MW, 50th MW, 52th MW). The rice crop sown during *rabi* season,S_4 (the 52th MW) date of sowing recorded significantly maximum protein content (6.27%) as compared to crop sown during S_2 (48th MW) and S_3 (50thMW). Rice genotype V_{28} i.e. IRRI-53 recorded significantly maximum protein content (7.09%) which was at par withV_{35} i.e. Ambpandhari (7.04%). The rice genotype Ratnagiri-711 recorded significantly minimum protein content (5.20%) which was at par with Sahyadri-2 (5.23%). The rice crop sown S_1i.e. *kharif* season (24th MW) with genotype V_{35} i.e. Ambepandhari recorded significantly higher protein content (6.84%).In case of *rabi* season S_4V_{28} i.e. crop sown in S_4 date of sowing (52th MW) with IRRI-55 was recorded significantly higher protein content (7.67%). However, S_2V_6 with rice genotype Ratnagiri-711 recorded significantly minimum protein content (5.03%) which was at par with S_2V_6 (5.03%) and S_2V_{34} (5.10%).

Varietal difference for protein content was also observed the variation in protein content between brown and white rice is because of bran portion, which is higher in protein and significantly increase the protein content of brown rice as reported earlier. Ahmed *et al*. (1998) [2] reported that the crude protein content of nine aromatic rice cultivars ranged from 9.17 to 11.77%. Buresova *et al*. (2010) [7] studied the variation in protein value in different aromatic rice varieties could be due to the application of fertilizer (nitrogen content), growing conditions and time and also location of growing areas. The highest protein content (12.4%) was assessed in cv. Kitaro. The lowest protein content (8.0%) was found in a sample of cv. Lupus. Abdul Baset Mia *et al.* (2012) [1] results showed that highest protein content was recorded in Binasail (10.53%). Other cultivars showed similar protein content and they were statistically identical. Gimhavanekar *et al.* (2020) [16] observed that rice varieties Karjat -3 and Karjat -7 recorded 6.70% and 5.40% protein content. Qian Zang *et al.* (2022) observed that protein content of NJ46 showed TP>DS. The amylose content was lower at EH than MH, but protein content was opposite i.e.higher trend. Rikako shimoyangi conducted experiment with different transplanting dates (20th May, 3rd June, 17th June) and observed that high temperature during grain filling decreased amylose but increased protein content.

3. Nitrate reductase activity (µmol/g)

Reduced nitrate reductase (NRase) activity which indicated disruption in nitrogen metabolism under water deficit condition (Parthasarathi *et al*., 2012) [23]. It plays a central role in plant primary metabolism and exhibits complex regulation mechanism for its catalytic activity (Dehghanpour *et al.*, 2011) [9].

In the present investigation, crop sown during S_1–*kharif* season (24th MW) produced significantly minimum nitrate reductase activity 1.562 µmol g-1 and 1.923 µmol g-1 at tillering and flowering stage respectively compared to other sowing dates of *rabi* season (48th MW, 50th MW, 52th MW).The rice crop sown during *rabi* season, S_4 (the 52th MW) date of sowing recorded significantly maximum nitrate reductase activity 2.131 µmolg^{-1} and 2.469 µmolg^{-1} at tillering and flowering stage. The rice genotype Ananda recorded significantly minimum nitrate reductase activity (1.440 µmolg^{-1}). Rice genotype V_2 i.e. Karjat-3 recorded significantly maximum nitrate reductase activity (2.357 µmolg^{-1}). At flowering stage, rice genotype V_2-Karjat-3 recorded significantly maximum nitrate reductase activity (2.674 µmolg^{-1}) which was followed bygenotypeV_6 i.e. Sahyadri-2 (2.661 µmolg^{-1}), V_7-Sahyadri-4 (2.658 µmolg^{-1}), V_{39}-Sorati (2.614 µmolg^{-1}), V_{40}-Mhadi (2.606 µmolg^{-1}). The rice crop sown S_1i.e. *kharif* season (24th MW) with genotype V_{39} i.e. Sorati recorded significantly higher nitrate reductase activity (2.400 µmolg^{-1}). *Rabi* season S_4V_{40} i.e. crop sown in S_4 date of sowing (52th MW) with Mhadi was recorded significantly higher nitrate reductase activity (2.400 µmolg^{-1}). However, S_2V_{34} with rice genotype. Ananda recorded significantly minimum nitrate reductase activity (1.672 µmolg^{-1}). NRA was gradually increased at tillering to flowering stages. Similar result obtained by Abdul *et al*. (2012) [1] studied the maximum NRA was attained at flowering stage as compared to panicle initiation and tillering stages and NRA was gradually increased at tillering to flowering stages. At tillering stage, BRRIdhan32 showed the highest amount of NRA and Binasail recorded the lowest amount of NRA the leaf nitrate reductase activity declined under heat stress. The percent reduction in NR activity was observed maximum in genotype IET 20924 (36%) and minimum in IET 20734 (3.00%). Gimhavanekar *et al.* (2020) [16] observed that maximum nitrate reductase activity was recorded in aromatic rice genotypes, Basmati-63 (4.62 umol g^{-1}). which was at par with phuleradha (3.88 umol g^{-1}) over other rice genotypes. The minimum nitrate reductase activity was recorded in katechinoor (1.16 umol g^{-1}). NRA was gradually increased at tillering to flowering stages.

4. Amylose content (%)

Hardness and stickiness of cooked rice is determined by Amylose content (Srivastava and Jaiswal, 2013) [31]. Rice with high amylose content show high volume expansion during cooking and cook dry, less tender and become hard upon cooling, while low amylose varieties cook moist and sticky (Juliano, 1985) [17].

In the present investigation, crop sown during S_1–*kharif* season (24th MW) produced significantly maximum amylose content (22.46%) as compared to other sowing dates of *rabi* season (48th MW, 50th MW,52th MW). The rice crop sown during *rabi* season, S_2 (the 48th MW) date of sowing recorded significantly maximum amylose content (22.03%) which was superior over others crop sown during S_3 (50th MW) and S_4 (52thMW).The rice variety Karjat-7 recorded significantly maximum amylose content (24.59%) followed by variety IRRI-34 (24.50%) and IRRI-62 (24.35%).Rice variety V_7 i.e. Sahyadri-4 recorded significantly minimum amylose content (19.38.%) which was followed by V_6 i.e.Sahyadri-2 (19.91%.).The rice crop sown S_1i.e.*kharif* season (24th MW) with genotype V_4 i.e. Karjat -7 recorded significantly higher amylose content (24.92%).In case of *rabi* season S_2V_4 i.e. crop sown in S_2 date of sowing (48th MW) with Karjat-7 was recorded significantly maximum amylose content (%) (24.65%) which was at par with S_2V_{23} (24.60%) i.e. crop sown in S_2 date of sowing (48th MW) and S_3V_4 (24.55%) i.e. crop sown in S_3 date of sowing (50th MW).

The varietal difference for amylose content was also reported by Sagar *et al.* (1988) observed that the amylose content ranged from 20.00-27.70% with a mean of 22.10% in aromatic rice grains. Asaduzzaman *et al.* (2013) [5] observed the variation of amylose content among different aromatic rice varieties was 15.69 to 23.01/100 g. Gimhavanekar *et al.* (2020) [16] observed that rice varieties *viz ly*; Karjat -3 and Karjat -7 recorded 24.07% and 23.36%amylose.

5. Iron content (ppm) (Fe)

In the present investigation, crop sown during S_1–*kharif* season (24th MW) produced significantly maximum iron content (8.68 ppm) as compared to other sowing dates of *rabi* season (48th MW, 50th MW,52th MW). The rice crop sown during *rabi* season, S_4(the 52th MW) date of sowing recorded significantly maximum iron content (10.27 ppm) as compared to crop sown during S_2 (48th MW) and S_3 (50th MW). The rice genotype V_{31}-Laldodaki recorded significantly minimum iron content (5.17 ppm). Rice genotype V_3-Karjat-4 recorded significantly maximum iron content (20.93 ppm) which was followed by V_{12} i.e. Ratnagiri-7 (15.56 ppm) and V_{38}i.e. Sorati (11.68 ppm). The rice crop sown S_1 i.e. *kharif* season (24th MW) with genotype V_3 i.e. Karjat-4 recorded significantly maximum iron content (18.94 ppm). In case of *rabi* season S_4V_{12} i.e. crop sown in S_4 date of sowing (52th MW) with Karjati-4 was recorded significantly higher iron content (17.02 ppm). However, $S_2V_{31}$with rice genotype Laldodki recorded significantly minimum iron content (4.71 ppm). Reported similar finding. Dutta and Barua (1978) [10] conducted field experiment at Jorhat for evaluation of nutritional quality of some rice varieties grown in Assam and found that iron content in different in different rice varieties varied from 1.66 to 1.92 mg per 100 g rice and observed highest in Chinese-63 and lowest in Ghee bora.

Kumar and Kapoor (1984) [19] studied mineral composition of different varieties of cereals and legumes at Hissar and observed 4.16,4.16 and 4.15 mg iron per 100 g rice in Pusa-221, Jhona -349 and Basmatti-370 respectively.

Patil (1985) [24] conducted field experiment at Dapoli for evaluation of quality characteristics of promising rice varieties grown in Konkan and revealed that iron content in rice varieties varied from 2.26 to 9.54 mg per 100 g rice.

Table 1: Effect of different treatments on biochemical analysis of rice genotypes

Sr. No	Genotypes	Carbohydrate content (%)	Protein (%)	Nitrate reductase activity (µmol/g)		Amylose content (%)	Iron (ppm)	Zinc (ppm)
A] Main plot (Date of sowing)				Tillering	Harvesting			
	S_1: 24th MW	78.68	5.75	1.562	1.923	22.46	8.68	13.1
	S_2: 48th MW	80.61	5.81	1.831	2.187	22.03	9.21	13.6
	S_3: 50th MW	81.40	6.01	1.984	2.308	21.71	9.65	14.1
	S_4: 52th MW	82.18	6.27	2.131	2.469	21.25	10.27	14.8
	SE ±	0.028	0.008	0.017	0.013	0.012	0.016	0.006
	C.D. at 5%	0.099	0.028	0.060	0.046	0.043	0.055	0.022
B) Sub plot (Varieties)								
1	V_1: Karjat-1	82.11	6.81	1.863	2.220	21.53	9.86	17.7
2	V_2: Karjat-3	81.61	5.59	2.357	2.674	23.49	7.97	10.2
3	V_3: Karjat-4,	80.18	6.64	1.671	2.094	23.71	20.93	9.7
4	V_4: Karjat-7	82.04	5.91	2.068	2.368	24.59	7.85	17.3
5	V_5: Karjat-184	79.30	5.45	2.040	2.402	20.67	10.82	12.8
6	V_6: Sahyadri-2	82.78	5.23	2.339	2.661	19.91	6.71	11.0
7	V_7: Sahyadri-4	83.23	5.31	2.350	2.658	19.38	8.50	13.9
8	V_8: Phondaghat -1	81.29	6.14	1.841	2.172	20.69	9.82	10.6
9	V_9: Ratnagiri-1	82.28	6.71	2.129	2.510	22.12	10.54	11.2
10	V_{10}: Ratnagiri-5	80.98	5.34	1.929	2.247	20.90	8.72	11.7
11	V_{11}: Ratnagiri- 6	78.22	6.48	1.886	2.241	21.42	10.10	20.3
12	V_{12}: Ratnagiri- 7	80.27	5.35	1.975	2.341	19.86	15.56	19.7
13	V_{13}: Ratnagiri -24	73.89	5.40	1.733	2.057	20.93	8.16	17.5
14	V_{14}: Ratnagiri-73	81.78	6.31	2.066	2.377	23.61	8.74	15.2
15	V_{15}: Ratnagiri-711	82.77	5.20	1.918	2.240	21.88	9.09	16.5
16	V_{16}: IRRI-14	81.75	6.16	1.705	2.034	23.13	7.65	11.6
17	V_{17}: IRRI-15	80.37	6.11	1.738	2.043	21.50	6.91	11.0
18	V_{18}: IRRI-20	82.28	6.69	1.957	2.273	20.49	8.28	12.5
19	V_{19}: IRRI-21	79.78	6.22	1.721	2.046	21.39	7.40	11.4
20	V_{20}: IRRI-22	79.70	5.48	1.705	2.047	21.18	7.74	11.8
21	V_{21}: IRRI-27	79.35	5.53	1.905	2.264	22.14	9.52	10.7
22	V_{22}: IRRI-28	79.30	5.28	1.626	1.965	22.27	8.98	13.0
23	V_{23}: IRRI-34	78.51	6.53	2.147	2.562	24.50	6.87	10.9
24	V_{24}: IRRI-36	79.01	5.84	2.078	2.448	23.86	7.22	11.4
25	V_{25}: IRRI-47	80.98	5.88	1.533	1.914	20.97	10.19	7.9
26	V_{26}: IRRI-52	79.30	5.44	1.449	1.782	23.24	6.43	10.4
27	V_{27}: IRRI-53	78.39	6.09	1.667	2.003	23.34	11.40	14.3
28	V_{28}: IRRI-55	81.83	7.09	1.493	1.830	21.90	8.52	15.6
29	V_{29}: IRRI-62	79.28	6.27	1.859	2.208	24.35	10.55	17.6
30	V_{30}: IR-35	82.11	5.80	1.843	2.157	21.23	11.09	18.2
31	V_{31}: Laldodaki	81.04	6.00	1.761	2.062	20.31	5.17	12.2
32	V_{32}: IR2289-6-22-5	81.27	5.41	1.918	2.258	20.77	11.16	13.2
33	V_{33}: Narmada	78.44	6.24	1.898	2.243	21.41	10.74	17.8
34	V_{34}: Ananda	79.97	5.36	1.440	1.777	20.29	11.46	18.9
35	V_{35}: Ambpandhari	78.80	7.04	1.672	2.029	20.55	9.31	16.3
36	V_{36}: Hira	82.46	5.93	1.740	2.096	22.37	8.12	13.9

37	V_{37}: OR-1516-1-5-A	79.66	5.49	1.586	1.957	21.39	9.52	16.5
38	V_{38}: China	82.18	6.01	1.892	2.229	22.29	9.07	16.1
39	V_{39}: Sorati	82.60	5.90	2.218	2.614	22.04	11.68	10.1
40	V_{40}: Mhadi	81.41	6.16	2.235	2.606	21.12	9.15	16.2
	SE+	0.042	0.023	0.032	0.011	0.026	0.049	0.038
	CD at 5%	0.116	0.063	0.088	0.031	0.072	0.136	0.106
Interaction Effect (S x M)								
	SE+	0.083	0.045	0.063	0.022	0.052	0.098	0.076
	CD at 5%	0.231	0.126	0.175	0.062	0.144	0.272	0.212
	General mean	80.716	5.957	1.877	2.222	21.862	9.447	13.902

S_1: 24th MW (11th-17th June) S_2: 48th MW (26th November-2nd December)
S_3: 50th MW (10th-16th December) S_4:52th MW (24th-31st December)

Table 2: Interaction effect of carbohydrate (%) on sowing dates and varieties (Pooled)

Sowing dates	Varieties									
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**
S1	79.67	80.88	79.33	80.22	78.27	81.57	82.57	78.57	81.25	80.30
S2	82.53	81.60	79.70	81.20	78.95	82.02	82.88	81.30	81.95	80.48
S3	82.95	81.80	80.55	81.27	79.52	83.17	83.50	82.50	82.75	81.32
S4	83.28	82.17	81.15	85.48	80.47	84.37	83.98	82.80	83.15	81.83
Sowing dates	**Varieties**									
	V11	**V12**	**V13**	**V14**	**V15**	**V16**	**V17**	**V18**	**V19**	**V20**
S1	74.17	79.42	78.70	80.27	81.25	80.72	78.47	79.63	78.37	78.58
S2	78.77	79.97	79.97	81.58	82.40	81.58	80.03	82.50	78.92	79.58
S3	79.73	80.42	80.65	81.97	83.38	82.03	81.07	83.15	80.42	80.02
S4	80.20	81.27	80.88	83.30	84.05	82.68	81.92	83.82	81.43	80.62
Sowing dates	**Varieties**									
	V21	**V22**	**V23**	**V24**	**V25**	**V26**	**V27**	**V28**	**V29**	**V30**
S1	76.48	76.23	76.27	77.18	78.33	76.40	75.48	79.25	76.28	80.17
S2	79.57	79.17	78.03	78.85	81.62	79.12	78.65	82.17	79.45	81.03
S3	80.13	80.42	79.52	79.38	81.77	80.53	79.47	82.57	80.15	83.18
S4	81.20	81.37	80.23	80.63	82.22	81.13	79.95	83.33	81.25	84.05
Sowing dates	**Varieties**									
	V31	**V32**	**V33**	**V34**	**V35**	**V36**	**V37**	**V38**	**V39**	**V40**
S1	78.20	80.12	76.22	76.07	77.08	80.20	77.60	78.35	79.95	79.02
S2	81.08	81.28	77.98	81.03	78.47	82.48	79.37	82.88	82.78	81.52
S3	82.20	81.83	79.28	81.20	79.35	83.23	80.42	83.53	83.40	82.20
S4	82.67	81.85	80.27	81.58	80.28	83.92	81.25	83.93	84.28	82.90
SE ±		0.083								
C.D. at 5%		0.231								

Table 3: Interaction effect of protein content (%) on sowing dates and varieties (Pooled).

Sowing dates	Varieties									
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**
S1	6.52	6.22	6.47	5.55	5.14	5.02	5.09	6.65	6.50	6.03
S2	6.69	5.16	6.42	5.97	5.36	5.10	5.21	5.86	6.29	4.99
S3	6.92	5.43	6.71	6.01	5.62	5.20	5.26	5.96	6.50	5.09
S4	7.12	5.54	6.95	6.10	5.69	5.61	5.67	6.07	7.58	5.25
Sowing dates	**Varieties**									
	V11	**V12**	**V13**	**V14**	**V15**	**V16**	**V17**	**V18**	**V19**	**V20**
S1	6.22	5.16	5.16	6.40	4.94	6.63	5.66	6.39	6.02	5.34
S2	6.20	5.36	5.92	5.99	5.03	5.95	6.03	6.62	5.98	5.23
S3	6.61	5.31	5.94	6.20	5.22	6.04	6.36	6.60	6.38	5.66
S4	6.91	5.60	6.38	6.66	5.59	6.03	6.39	7.17	6.51	5.71
Sowing dates	**Varieties**									
	V21	**V22**	**V23**	**V24**	**V25**	**V26**	**V27**	**V28**	**V29**	**V30**
S1	5.30	5.07	6.21	5.34	5.46	4.98	6.07	6.63	5.96	6.25
S2	5.35	5.09	6.22	5.73	5.85	5.46	6.02	6.93	6.14	5.46
S3	5.72	5.42	6.66	6.09	6.00	5.43	6.10	7.16	6.46	5.50
S4	5.76	5.55	7.01	6.20	6.22	5.89	6.16	7.67	6.54	5.98
Sowing dates	**Varieties**									
	V31	**V32**	**V33**	**V34**	**V35**	**V36**	**V37**	**V38**	**V39**	**V40**
S1	5.43	4.92	5.92	5.09	6.84	5.40	4.96	5.56	5.71	5.67
S2	6.01	5.42	6.00	5.06	6.86	5.90	5.53	6.02	5.87	6.00
S3	6.16	5.57	6.26	5.40	7.07	6.13	5.62	6.21	5.96	6.32
S4	6.41	5.74	6.78	5.91	7.39	6.31	5.86	6.24	6.07	6.65
SE ±		0.045								
C.D. at 5%		0.126								

Table 4: Interaction effect of nitrate reductase activity (µ mol g-1) on sowing dates and varieties. (Pooled).

Sowing dates	Varieties									
	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
S1	2.095	2.370	2.010	2.323	2.210	2.368	2.170	1.922	2.073	1.735
S2	2.098	2.563	1.928	2.262	2.257	2.670	2.672	2.172	2.518	2.333
S3	2.303	2.720	2.087	2.383	2.460	2.732	2.850	2.232	2.662	2.410
S4	2.383	3.042	2.352	2.503	2.682	2.873	2.940	2.363	2.785	2.508
Sowing dates	Varieties									
	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20
S1	2.005	2.015	1.992	2.135	1.858	1.882	1.745	1.898	1.793	1.662
S2	2.272	2.285	2.177	2.272	2.192	1.982	2.018	2.228	1.990	1.897
S3	2.303	2.440	2.238	2.393	2.385	2.027	2.055	2.450	2.067	2.123
S4	2.385	2.623	2.507	2.708	2.527	2.245	2.353	2.517	2.333	2.507
Sowing dates	Varieties									
	V21	V22	V23	V24	V25	V26	V27	V28	V29	V30
S1	1.897	1.767	2.050	1.882	1.592	1.612	1.623	1.673	1.748	1.868
S2	2.223	1.903	2.535	2.505	1.917	1.688	2.047	1.755	2.297	2.112
S3	2.363	1.992	2.723	2.635	1.993	1.838	2.132	1.867	2.342	2.250
S4	2.572	2.200	2.938	2.770	2.153	1.988	2.212	2.023	2.445	2.398
Sowing dates	Varieties									
	V31	V32	V33	V34	V35	V36	V37	V38	V39	V40
S1	1.758	1.873	1.868	1.670	1.778	1.783	1.655	1.930	2.228	2.400
S2	1.990	2.227	2.360	1.672	1.985	2.078	1.903	2.207	2.663	2.638
S3	2.173	2.403	2.292	1.853	2.168	2.228	2.047	2.312	2.738	2.662
S4	2.327	2.530	2.450	1.912	2.185	2.293	2.222	2.468	2.825	2.725
SE ±		0.022								
C.D. at 5%		0.062								

Table 5: Interaction effect of amylase content (%) on sowing dates and varieties. (Pooled).

Sowing dates	Varieties									
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
S1	22.23	24.18	24.46	24.92	21.23	20.65	19.96	21.19	22.71	21.52
S2	21.64	23.64	23.81	24.65	20.89	20.32	19.56	20.89	22.33	21.05
S3	21.34	23.20	23.63	24.55	20.59	19.61	19.17	20.69	21.95	20.72
S4	20.93	22.94	22.96	24.26	19.97	19.08	18.85	20.00	21.51	20.33
Sowing dates	Varieties									
	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20
S1	21.80	20.38	23.04	24.03	22.77	23.66	21.93	21.26	22.02	21.82
S2	21.50	20.09	22.60	23.52	21.77	23.25	21.74	20.58	21.69	21.28
S3	21.35	19.61	22.60	23.49	21.65	22.94	21.35	20.22	21.62	21.11
S4	21.03	19.35	22.46	23.39	21.32	22.69	21.00	19.92	20.21	20.52
Sowing dates	Varieties									
	V21	V22	V23	V24	V25	V26	V27	V28	V29	V30
S1	22.62	23.14	24.88	24.52	22.11	24.28	23.81	22.90	24.79	21.90
S2	22.44	22.49	24.60	24.09	21.07	23.09	23.41	22.19	24.47	21.76
S3	21.91	22.01	24.47	23.65	20.60	22.94	23.19	21.55	24.21	21.33
S4	21.60	21.43	24.03	23.16	20.11	22.64	22.93	20.96	23.95	19.94
Sowing dates	Varieties									
	V31	V32	V33	V34	V35	V36	V37	V38	V39	V40
S1	20.79	21.20	21.81	21.00	21.22	23.02	22.01	22.71	22.50	21.61
S2	20.65	21.00	21.67	20.36	20.88	22.73	21.68	22.27	22.28	21.33
S3	20.20	20.55	21.19	20.29	20.39	22.11	21.38	22.12	21.90	20.87
S4	19.61	20.35	20.97	19.50	19.70	21.63	20.49	22.05	21.50	20.68
SE ±		0.052								
C.D. at 5%		0.144								

Table 6: Interaction effect of iron content (ppm) on sowing dates and varieties. (Pooled)

Sowing dates	Varieties									
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**
S1	8.08	6.03	18.94	8.32	8.80	5.77	7.48	10.15	9.40	7.97
S2	10.43	8.38	21.33	6.37	10.66	6.42	8.56	9.22	10.58	8.46
S3	10.36	8.27	21.55	7.61	11.52	6.83	8.75	9.68	10.71	8.69
S4	10.59	9.19	21.91	9.10	12.28	7.82	9.21	10.22	11.47	9.76
Sowing dates	**Varieties**									
	V11	**V12**	**V13**	**V14**	**V15**	**V16**	**V17**	**V18**	**V19**	**V20**
S1	8.92	13.60	9.27	8.24	10.33	6.86	6.04	7.18	6.38	7.61
S2	9.57	15.24	8.12	8.62	8.20	7.00	6.45	7.56	6.58	6.88
S3	9.97	16.37	8.51	9.04	8.57	7.80	6.93	9.06	7.69	7.70
S4	11.92	17.02	9.48	9.06	9.27	8.95	8.24	9.33	8.96	8.77
Sowing dates	**Varieties**									
	V21	**V22**	**V23**	**V24**	**V25**	**V26**	**V27**	**V28**	**V29**	**V30**
S1	9.04	7.70	7.69	6.62	9.36	7.42	11.42	7.10	8.82	9.50
S2	9.66	8.61	6.40	6.99	10.23	5.35	11.13	8.43	10.37	11.04
S3	9.62	9.46	6.36	7.60	10.39	6.17	11.32	9.13	11.27	11.49
S4	9.79	10.16	7.03	7.67	10.80	6.77	11.71	9.41	11.74	12.34
Sowing dates	**Varieties**									
	V31	**V32**	**V33**	**V34**	**V35**	**V36**	**V37**	**V38**	**V39**	**V40**
S1	5.12	10.17	8.96	11.22	8.71	5.85	10.16	8.43	10.20	8.41
S2	4.71	11.06	10.94	11.33	9.24	9.21	8.96	9.12	11.90	9.29
S3	5.10	11.65	11.30	11.25	9.82	8.32	9.63	9.37	12.13	9.21
S4	5.73	11.76	11.76	12.07	9.46	9.10	9.34	9.37	12.50	9.71
SE ±		0.098								
C.D. at 5%		0.272								

Table 7: Effect of different treatment on zinc content (ppm) of rice genotypes. (Pooled)

Sowing dates	Varieties									
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**
S1	16.22	8.62	8.35	15.74	10.69	9.53	12.45	10.87	10.27	10.76
S2	17.81	10.30	9.53	17.04	12.58	10.66	13.54	9.92	10.97	11.52
S3	18.35	10.57	10.18	17.83	13.78	11.76	14.35	10.42	11.38	11.71
S4	18.42	11.14	10.63	18.56	14.28	12.09	15.31	11.12	11.99	12.68
Sowing dates	**Varieties**									
	V11	**V12**	**V13**	**V14**	**V15**	**V16**	**V17**	**V18**	**V19**	**V20**
S1	18.98	17.34	19.27	14.29	17.58	10.80	10.13	11.01	10.51	11.75
S2	19.63	19.36	18.17	15.02	15.11	11.09	10.49	11.85	10.63	11.03
S3	20.29	20.48	18.73	15.43	15.71	11.85	11.16	13.09	11.59	11.81
S4	22.11	21.43	19.50	15.96	17.61	12.83	12.31	14.04	13.04	12.68
Sowing dates	**Varieties**									
	V21	**V22**	**V23**	**V24**	**V25**	**V26**	**V27**	**V28**	**V29**	**V30**
S1	10.59	11.59	11.62	10.78	7.09	11.24	15.41	14.02	15.77	16.51
S2	10.54	12.82	10.46	11.13	7.89	9.43	12.54	15.52	17.57	18.02
S3	10.76	13.40	10.57	11.82	8.13	10.30	13.51	16.17	18.42	18.66
S4	11.08	14.26	10.88	12.05	8.52	10.79	15.75	16.49	18.72	19.45
Sowing dates	**Varieties**									
	V31	**V32**	**V33**	**V34**	**V35**	**V36**	**V37**	**V38**	**V39**	**V40**
S1	12.23	12.20	15.84	18.11	15.80	13.01	16.89	15.16	9.36	15.72
S2	11.51	13.18	18.05	18.39	16.29	14.16	16.18	16.07	10.19	16.12
S3	12.13	13.51	18.61	18.60	16.62	13.97	16.62	16.47	10.40	16.24
S4	12.84	13.89	18.81	20.50	16.38	14.54	16.24	16.74	10.26	16.76
SE ±		0.076								
C.D. at 5%		0.212								

Singh *et al* (1998) [30] studied quality characteristics of six rice varieties grown in Himachal Pradesh and observed that iron content of brown rice varied from 2.41 to 4.50 mg per 100 g rice while that of milled rice varied from 1.21 to 3.06 mg per 100 g rice.

Ghadi (2001) [15] during quality evaluation of promising rice varieties grown in Konkan region at Dapoli found that the content of iron in twelve rice varieties ranged from 6.34 to 13.81 mg per 100 g rice respectively.

Amudha *et al.* (2007) [3] while studying nutritional aspects of rice observed that the iron content in all the six genotypes ranged between 10.85 to 16.42 mg per 100 g in brown rice samples and between 8.95 to 14.72 mg per kg in polished rice samples.

6. Zinc (ppm) (Zn)

Results were in accordance with the finding of Sanjeev Roa *et al*. (2007) [27] studied zinc content of the popular varieties of rice as 13 mg/kg and RDA of zinc as 12 mg/kg for male and 10 mg/kg for female, the zinc intake through rice consumption is 2.9 g/day per person.

Crop sown during S_1–*kharif* season (24th MW) produced significantly maximum iron content (13.1 ppm) as compared to other sowing dates of *rabi* season (48th MW, 50th MW, 52th MW). The rice crop sown during *rabi* season,S_4(the 52th MW) date of sowing recorded significantly maximum zinc content (14.8 ppm) as compared to crop sown during S_2 (48th MW) and S_3 (50thMW).The rice genotype V_{11} i.e. Ratnagiri-6 recorded significantly maximum zinc content (20.3 ppm) followed by genotype V_{34} i.e. Ananda (18.9) and V_{12} i.e. Ratnagiri-7(17.3ppm).The rice crop sown S_1i.e.*kharif* season (24th MW) with genotype V_7 i.e. Sahyadri-4 recorded significantly higher zinc content (%).In case of *rabi* season S_4V_{11} i.e. crop sown in S_4 date of sowing (52th MW) with Ratnagiri-6 treatment combination was recorded significantly higher zinc content (22.11 ppm).However,S_2V_{25} with rice variety IRI-47 recorded significantly minimum zinc content (7.89 ppm).

Conclusion

In conclusion, study showed that the rice crop sown during *rabi* season, S_4 (the 50th MW) date of sowing recorded significantly maximum carbohydrate content (82.18%) as compared to other sowing. V_7 i.e. Sahyadri-4 recorded significantly maximum carbohydrate content (83.23%). S_4 (the 52th MW) date of sowing recorded significantly maximum protein content (6.27%) as compared to other sowing. V_{28} i.e. IRRI-53 recorded significantly maximum protein content (7.09%) which was at par withV_{35} i.e. Ambpandhari (7.04%). The rice crop sown during *rabi* season, S_4 (the 52th MW) date of sowing recorded significantly maximum nitrate reductase activity 2.131 $\mu molg^{-1}$ and 2.469 $\mu molg^{-1}$ at tillering and flowering stage. S_1– *kharif* season (24th MW) produced significantly maximum amylose content (22.46%) as compared to other sowing dates of *rabi* season (48th MW, 50th MW, 52th MW). S_1– *kharif* season (24th MW) produced significantly maximum iron content (8.68ppm) as compared to other sowing dates of *rabi* season (48th MW, 50th MW, 52th MW). S_1–*kharif* season (24th MW) produced significantly maximum iron content (13.1ppm) as compared to other sowing dates of *rabi* season (48th MW, 50th MW, 52th MW).

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