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Effects of sowing dates and irrigation regimes on grain quality of wheat grown under semi-arid condition of India

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Abstract: An experiment was conducted with aim to investigate the effect of sowing dates and irrigation regimes on wheat grain quality. There was four sowing dates [November 1(S_1), November 16 (S_2), December 1(S_3) and December 16 (S_4)], in main plots and four irrigation regimes [25% (I_1), 50% (I_2) and 75% (I_3) maximum allowable depletion (MAD) of available soil moisture (ASM) and I_4 – four critical growth stages in sub plots. The results revealed that hectolitre weight decreased from 80.2 and 81.4 kg hl^{-1} in S_1 treatment to 78.3 and 79.4 kg hl^{-1} in S_4 treatment and 79.9 and 81.5 kg hl^{-1} in I_1 treatment to 79.0 and 79.9 kg hl^{-1} in I_3 treatment in 2010-11 and 2011-12, respectively. Grain hardness outcome was ≥75 in 2010-11 while it was <75 in 2011-12 irrespective of sowing dates and irrigation regimes. The highest percentage of flour recovery obtained in S_1 treatment (68.2 and 63.2%) and I_1 treatment (68.0 and 62.8%) with lowest coarse bran. On average, dry gluten content increased by 16.5 and 7.1% in S_4 over S_1 treatment in 2010-11 and 2011-12, respectively. Grain protein content increased from 11.9 and 12.8% in S_1 treatment to 12.6 and 13.8% in S_4 treatment in respective seasons. The milling and technological properties in S_2 and I_2 treatment was at par with S_1 and I_2 treatment. Therefore, it may be inferred that optimum milling and technological properties of wheat grain can be maintained by sowing till mid-November and irrigation scheduling up to 50% depletion of ASM.

Keywords: Irrigation regime, Maximum allowable depletion, Sowing date, Wheat quality

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important staple food crops and reportedly contributes 28% of the world edible dry matter and provides up to 60% of daily calorie uptake in developing country and leading source of vegetable protein among cereals in human food (Singh *et al*., 2010 and 2012). As much of wheat production consumed by human, the quality of wheat grain flour has marked effects on human nutrition and health. In India, 75% of wheat production is milled into flour to make *chapati*/*roti* (unleavened flat bread). With changing consumption pattern as a result of urbanization, increased purchasing powers, substitution to other cereals and awareness of consumers, the demand for wheat based value added products is expected to rise further in near future. The quality requirement for wheat based products are different, hence, industry may also demand more product specific quality. With increasing market opportunities and entry of private sector in wheat industry, the demand for stable grain quality would increase in future (Coventry *et al*., 2011 a, b).

In semi-arid region of India, wheat grown on light textured soil frequently exposed to both moisture and high temperature stress during wheat growing season particularly at grain filling stage. The frequent exposure of crop to more than one extreme event in a single growing season influences crop yield and grain quality. The frequency of weather events and extremes likely to increase in future and thereby influence better grain quality, which going to be determinant of wheat grain price. Hence, farmers need a package of agronomic practices that ensure better grain quality in uncertain growing conditions. Amongst agronomic practices, the sowing time and irrigation plays an important role in influencing the quality of wheat grain. Ideal soil, water and climatic condition, prevailing in optimum sowing is responsible for quality of bread wheat with good hectolitre weight but grain protein content, dry gluten content and sedimentation index were obtained higher in late sown wheat (Zende *et al.,* 2005). By agronomic interventions such as proper sowing time and irrigation schedule ensure stable grain quality. Therefore, this paper seeks to clarify the effect of different sowing dates and irrigation regimes on wheat grain quality under semi arid condition of India.

MATERIALS AND METHODS

Experimental site, soil and climate: The study area was located at the experimental farm of Water

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Technology Centre, Indian Agricultural Research Institute (IARI), New Delhi (28 °38' 56.2" N, 77 °11' 37.6" E; 228.7 m above mean sea level), India. The field experiment was conducted for 2 consecutive *rabi* season of 2010-11 (Year I) and 2011-12 (Year II).

The soil of the study area is sandy loam (*Typic Haplustepts*) in texture with medium angular blocky structure and non-calcareous in nature. Chemically, soil is of neutral pH; low in organic carbon and available N; medium in available (Olsen) P and available K in 0-30 cm soil depth. The soil physical properties (0-30 cm) are bulk density: 1.52 Mg m^{-2}; saturated hydraulic conductivity: 1.09 cm h^{-1} and sand, silt and clay, 70.9, 12.8 and 16.9, respectively. Available soil moisture ranges from 17.2 % (field capacity) to 7.5 % (wilting point) in 0 to 0.90 m layers.

The region is characterized by a semi-arid and subtropical climate with hot dry summer (March-June), wet monsoon season (late June–mid September) and cold winter seasons (November-February) and falls under the agro-climatic zone of "Trans-Gangetic plains". The mean annual rainfall is 734 mm, of which approx. 80% falls during active south-west monsoon months from July to September.

Experimental design and treatments: The experimental design was a split-plot with replicated thrice. There were sixteen treatments, involving four sowing dates namely, S_1- November 1; S_2- November 16; S_3- December 1; S_4- December 16, in main plots and four irrigation regimes were, I_1 – 25% maximum allowable depletion (MAD) of available soil moisture (ASM), I_2 – 50% MAD of ASM, I_3 – 75% MAD of ASM, I_4– based on four (crown root initiation, late jointing, flowering and milking) critical growth stages, in sub-plots.

Crop cultivar, irrigation scheduling and agronomic practices: Wheat cultivar DBW-17, a semi-dwarf variety with 135-145 days cropping duration, was used for sowing. Wheat seeds were sown in rows 20 cm apart as per treatment schedule with seed rate @100 kg ha^{-1} (S_1 and S_2) and 110 kg ha^{-1}(S_3 and S_4) to maintain optimum plant population. The row orientation was north-south to facilitate favourable micro-climate. The plots dimensions were 5 x 4 m. The crop applied N @ 120 kg ha^{-1} with half dose of N (60 kg ha^{-1}) and full dose of P (60 kg ha^{-1}) and K (40 kg ha^{-1}) as basal and remaining N was applied in 2 equal doses, half at first and the rest half at second irrigation. The source of N, P, and K were urea, Diammonium phosphate (DAP) and murate of potash (MOP), respectively. Pre-emergence application of chloropyriphos (or confidor) and pendimethalin were given on same day after sowing followed by one weeding cum hoeing was done at 40 DAS and chloropyriphos (or confidor) applied whenever termite infestation appeared in the plots. The irrigation scheduling was done on the basis of soil moisture depletion in the root zone determined gravimetrically during cropping season.

The pre-defined level of MAD was calculated by the following equation (Martin *et al*., 1990):

$$\text{Depletion (\%)} = 100 \times \frac{1}{n}\sum^{n}\left(\frac{FCi - \theta i}{FCi - WP}\right)$$

Where, n is the number of sub-divisions of the effective rooting depth used in the soil moisture sampling, FC_i the soil moisture at field capacity for ith layer, θ_i the soil moisture in ith layer and WP the soil moisture at permanent wilting point.

The amount of water applied after the attainment of pre-defined MAD (%) was calculated as

$$Vd = \frac{MAD(FC - WP)\, Rz \times A}{100}$$

Where, V_d the volume of irrigation water applied, R_Z the effective rooting depth and A the surface area of the plot.

The irrigation interval and quantity of water applied during each irrigation events increased from I_1 to I_3 and I_4 given four irrigations critical growth stages. The plants were raised throughout the period from sowing to maturity according to recommended agronomic practices for wheat under irrigated condition. The crop was harvested manually at the physiological maturity. Crop yield was recorded as per the established procedure for each treatment. Daily meteorological data for the crop growing period were obtained from the Agro-meteorological observatory, located approx. 2.0 km from the experimental plot.

Milling tests: After threshing, random samples were taken from each treatment to evaluate grain quality. Wheat whole flour was obtained by milling grain samples using a Cyclotec 1093 sample mill (Foss, Tecator, Sweden). Percentage of flour recovery, coarse and fine bran were measured after grain milling by Quadrumat Senior mill (Brabender, Germany), which was operated for milling of 250 g grain sample to obtain flour (Method AACC 26-21A). The weight of flour and bran was taken separately and flour recovery percentage was calculated using the formula:

$$\text{Flour recovery percentage} = \frac{A}{A+B} \times 100$$

Where, A = Weight of flour
B = Weight of bran

The hectolitre weight was determined by taking wheat grains sample in 100 ml measuring cylinder, weighed and expressed as kg hl^{-1} (AACC, 1983). Grain hardness and diameter were measured by Single Kernel Characterization system (SKCS) 4100 (from Perten Instruments, Australia). Water absorption of dough was estimated by using Brabender Farinograph (AACC 54-21.01). Water absorption was estimated as the percentage of water in the dough for reaching strength of 500 BU.

Technological tests: The protein content in the grain samples were determined by Kjeldahl method using the Autokjeltech system 3100 (Foss, Tecator, USA).

Wet gluten content was determined by hand-washing method (AACC 38-10.01). Dry gluten was obtained after oven drying of the wet gluten sample (dough) at 105 °C for 6 hours. The sedimentation test was determined by sodium dodecyl sulphate (SDS) method as suggested by Axford *et al*. (1979). The grain quality analyses were carried out at Grain Quality Laboratory, IARI, New Delhi.

Statistical analysis: The data collected from laboratory were compiled and properly tabulated. These were subjected to statistical analysis by using 'Analysis of Variance Technique' as suggested by Gomez and Gomez (1983). Standard errors of mean and critical difference (CD) values at 5% level of probability were computed for making comparison between treatments.

RESULTS AND DISCUSSION

Weather growing conditions during the crop period: Daily air temperature, pan evaporation, relative humidity, sunshine hours and rainfall during the period of study are shown in Fig. 1. Data revealed that cropping season 2011-12 appeared relatively warmer during vegetative stage. Temperature (*T*max and *T*min) during reproductive stage follow same trend in both cropping years except heading to anthesis growth stage in November 1 and November 16 sowing, when *T*max and *T*min were found higher in 2010-11. The November 1 sowing experienced temperature in the ranges of 9.5- 24.1 °C and 6.9- 20.9 °C, while December 16 sowing in the range of 6.3- 20.3 °C and 13.5- 31.1°C during vegetative and reproductive stages of wheat, respectively. During reproductive stage, relatively lower temperature was noticed in November sowings and relatively higher temperature in December sowings. The different sowing dates selected in this study resulted in exposure of plants to varied temperatures events during reproductive period. The overall atmospheric evaporative demand was highest in 2011-12, ranges from 4.2 to 6.9 mm day^{-1}. The higher atmospheric evaporative demand (>4 mm day^{-1}) was observed during reproductive stage but it was 2.9 mm day^{-1} during February 2011. The average daily bright sunshine during crop growth periods were 5.5 and 5.2 h for 2010–11 and 2011–12, respectively. In 2011-12, rainfall was approximately lower than that in 2010-11. Total rainfall received by crop from sowing to maturity was 63.5 mm in 2010-11 higher than 40.8 mm in 2011-12 cropping season. There was a good

Table 1. Effect of sowing dates and irrigation regimes on milling properties of wheat grain.

Year		Hectolitre weight (kg hl^{-1})	Grain hardness (%)	Grain diameter (mm)	Flour recovery (%)	Water absorption of flour (%)
(Year I) 2010-11	Sowing date					
	S_1	80.24	85.83	2.87	68.23	56.23
	S_2	79.66	83.51	2.83	68.06	56.18
	S_3	79.31	81.17	2.79	67.26	55.90
	S_4	78.28	74.66	2.77	66.55	55.72
	Sem±	0.20	0.75	0.01	0.08	0.13
	C.D. (P=0.05)	0.70	2.62	0.05	0.30	0.48
	Irrigation regime					
	I_1	79.89	80.21	2.85	68.03	56.21
	I_2	79.54	80.35	2.83	67.86	56.06
	I_3	79.00	83.26	2.78	66.91	55.68
	I_4	79.05	81.35	2.80	67.29	56.08
	Sem±	0.23	0.87	0.02	0.10	0.06
	C.D. (P=0.05)	0.86	3.26	0.08	0.40	0.25
(Year II) 2011-12	Sowing date					
	S_1	81.40	73.83	2.90	63.16	62.03
	S_2	81.05	73.08	2.88	62.45	62.00
	S_3	80.51	72.08	2.86	61.76	62.00
	S_4	79.44	66.83	2.81	61.55	61.92
	Sem±	0.33	1.38	0.04	0.22	0.08
	C.D. (P=0.05)	1.15	4.76	0.14	0.78	0.29
	Irrigation regime					
	I_1	81.47	70.58	2.89	62.84	62.13
	I_2	80.53	70.92	2.88	62.41	62.10
	I_3	79.95	72.25	2.83	61.74	61.76
	I_4	80.44	72.08	2.84	61.94	62.00
	Sem±	0.23	0.81	0.03	0.21	0.09
	C.D. (P=0.05)	0.87	3.03	0.11	0.82	0.36

Table 2. Effect of sowing dates and irrigation regimes on technological properties of wheat grain.

Year		Protein content (%)	Wet gluten content (%)	Dry gluten content (%)	Sedimentation value (ml)	Coarse bran (%)	Fine bran (%)
(Year I) 2011	Sowing date						
	S_1	11.94	25.03	9.58	30.50	28.55	3.22
	S_2	12.18	25.59	9.97	31.67	29.18	2.76
	S_3	12.52	26.32	10.33	32.08	30.02	2.72
	S_4	12.56	28.92	11.12	32.08	30.52	2.93
	S_1	0.09	0.50	0.26	0.15	0.06	0.05
	C.D. (P=0.05)	0.34	1.74	0.90	0.55	0.22	0.18
	Irrigation regime						
	I_1	12.05	24.61	10.04	31.08	29.04	2.93
	I_2	12.30	27.01	10.23	31.17	29.19	2.95
	I_3	12.45	27.22	10.61	32.08	30.37	2.72
	I_4	12.40	27.01	10.12	32.00	29.66	3.05
	Sem±	0.10	0.67	0.20	0.25	0.10	0.08
	C.D. (P=0.05)	0.37	2.51	0.76	0.93	0.38	0.32
(Year II) 2012	Sowing date						
	S_1	12.77	31.69	11.11	33.75	34.45	2.39
	S_2	13.05	32.74	11.38	34.67	35.04	2.51
	S_3	13.34	33.24	11.61	34.75	35.75	2.49
	S_4	13.78	33.26	11.90	35.00	35.86	2.59
	Sem±	0.09	1.58	0.11	0.50	0.20	0.06
	C.D. (P=0.05)	0.32	5.47	0.38	1.73	0.72	0.23
	Irrigation regime						
	I_1	13.03	31.48	11.08	33.67	34.74	2.42
	I_2	13.24	31.96	11.53	34.42	35.01	2.58
	I_3	13.36	34.06	11.79	35.33	36.02	2.24
	I_4	13.32	33.42	11.60	34.75	35.33	2.73
	Sem±	0.14	1.64	0.22	0.38	0.23	0.04
	C.D. (P=0.05)	0.52	6.12	0.84	1.44	0.84	0.16

amount of rainfall in February (49.9 mm) in first year and January (14.8 mm) and March (19.2 mm) during second year of experimentation. The average relative humidity was 64 and 60% in respective years and the sky was cloud free for most of the time during crop growth period.

Milling characteristics

Hectolitre weight: The hectolitre weight (HW) was significantly affected by sowing dates and irrigation regimes (Table 1). In both seasons, HW varied between 78 and 81 kg hl^{-1} among sowing dates. The significantly highest HW (80.2 and 81.4 kg hl^{-1} in the first and second season, respectively) was observed in S_1, which was at par with S_2 and lowest in S_4 (78.3 and 79.4 kg hl^{-1}). Among irrigation regimes, the highest HW (79.9 and 81.5 kg hl^{-1}) was found in I_1 and lowest (79.0 and 79.9 kg hl^{-1}) was obtained in I_3 irrigation regime. The highest HW in S_1 might have occurred due to favourable prevailing temperature conditions. The decline in HW might be due to high temperature in S_3 and S_4 sowing and thus subjecting to forced maturity and drying of immature seeds at the time of grain filling, led to reduction in grain size and poor density and thereby lower HW. Kaur *et al*. (2010) found that HW decreased from 75.7 kg hl^{-1} in 15th November sowing to 73.1 kg hl^{-1} in 25th December sowing. Similarly, significantly decline in HW was observed due to delayed sowing in previous studies (Tyagi *et al*., 2003; Asseng *et al*., 2004). The HW decrease with increase in soil moisture depletion and recorded lowest in I_3 irrigation regime. Moisture stress during grain filling reduces HW as compared to treatments receiving frequent irrigation (I_1 and I_2). The probable reason for this is that the photosynthates deposited in grain are known to come from remobilization of assimilates deposited in other plant organs and photosynthesis of the flag leaf, stem and ear. The frequently irrigated treatments enabled the crop to accumulate sufficient carbohydrate reserve in leaf area to sufficiently provide source assimilates for grain filling as compared to less frequently irrigated regimes.

Grain hardness: Grain hardness (GH) was significantly affected by sowing dates in both seasons (Table 1). The GH outcome was ≥75 and <75 in 2010-11 and 2011-12, respectively irrespective of sowing dates and irrigation regimes. The highest GH outcome was observed in S_1 (85.8 and 73.8%) and lowest in S_4 (74.7 and 66.8%). The effect of irrigation regime on GH was

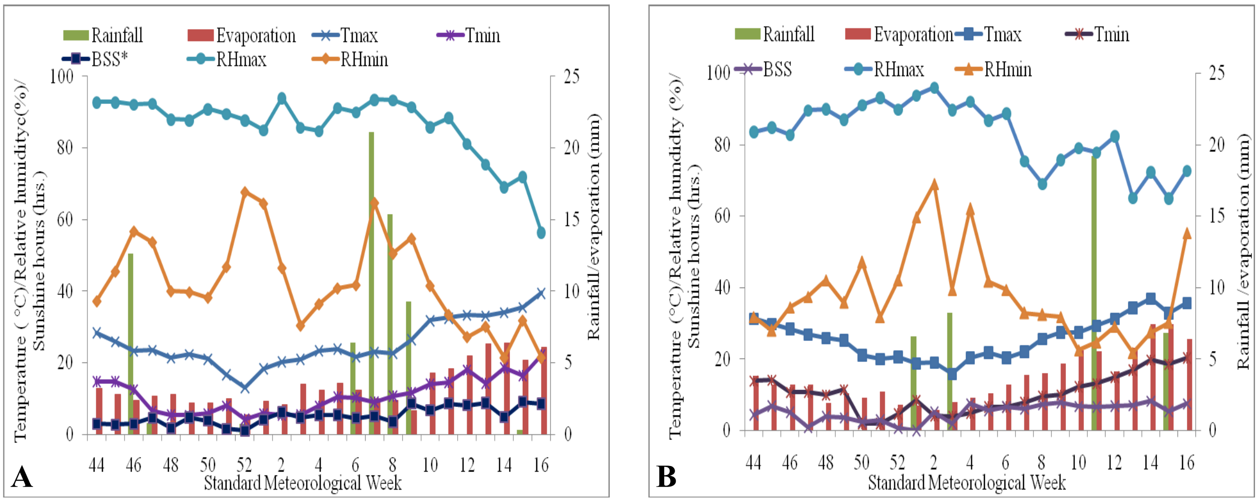

Fig. 1. *Weather conditions during cropping season 2010-11 (a) and 2011-12 (b).*

non-significant (Table 1). The highest GH was recorded in I_3 (83.3 and 72.3%) having less frequent irrigation and lowest in I_1 (80.2 and 70.6) irrigation regime in both seasons. GH outcome >75 is desired quality characteristics (Das *et al.*, 2006; Ram and Mishra, 2008). GH outcome >75 in 2010-11 was because of relatively cooler growing season. Such results were also obtained by Coventry *et al.* (2011 a, b).

Grain diameter: The effect of sowing dates on grain diameter (GD) was found significant in 2010-11 and non-significant in 2011-12 (Table 1). The highest GD (2.87 and 2.90 mm) was observed in S_1 followed by S_2, S_3 and lowest (2.77 and 2.81 mm) in S_4. The per cent increase was 3.6 and 3.2 in GD in S_1 over S_4 in 2010-11 and 2011-12, respectively. In both seasons, effect of irrigation regimes on GD was non-significant (Table 1). However, the highest GD (2.85 and 2.89 mm) was recorded in I_1 irrigation regime but was at par with I_2 and lowest (2.78 and 2.83 mm) in I_3 irrigation regime. There was an increase in GD by 1.8 and 1.7% in I_1 over I_3 in the first and second season, respectively. The lowest grain diameter (GD) in S_4 was because of reduced grain size associated with high temperature. The GD is affected by temperature and moisture stress during reproductive stage. Moisture stress might have terminated cell expansion, grain growth and affecting grain size through reduction in carbohydrate accumulation. These findings corroborate with earlier findings (Panazzo and Eagles, 2000; Waraich *et al.*, 2010; Coventry *et al.*, 2011b).

Flour recovery percentage: The flour recovery was significantly affected by different sowing dates and irrigation regimes (Table 1). The highest percentage of flour recovery (68.2 and 63.2%) was obtained in S_1 while lowest percentage of flour recovery (66.6 and 61.6%) recorded in S_4. Amongst irrigation regimes, the highest percentage of flour recovery (68.0 and 62.8%) was obtained in I_1 irrigation regime having more frequent irrigation, followed by I_2, I_4 and lowest in I_3 irrigation regime having lowest frequency of irrigation. The highest percentage of flour recovery in S_1 may be due to the increase in grain weight and size. The low values of flour recovery and higher percentage of coarse bran are associated with poorly filled, immature and shriveled grain that may yield less flour than sound grain. Similar results were also reported earlier (Seleiman *et al.*, 2011a). Frequent irrigation with small quantity as in I_1 led to a significant increase in flour recovery and decrease in coarse bran percentage. Variation in flour yield directly relates to differences in the proportion of endosperm in the kernel (Bergman *et al.*, 1998), which is influenced by grain weight and size as it is expected to be bold and non-shriveled grain in I_1. Such results were reported in previous studies (Zhou *et al.*, 2003; Zhang *et al.*, 2005; Seleiman *et al.*, 2011b).

Water absorption of flour: The effect of sowing date and irrigation regimes on water absorption is shown in Table 1. The highest water absorption was observed in S_1 (56.2 and 62.0%), which is at par with S_2 and lowest was observed in S_4. Irrigation had significant effect on water absorption of flour in 2010-11. The highest water absorption was observed in I_1 (56.2 and 62.1%) irrigation regime and lowest in I_3 (55.7 and 61.8%) in both seasons.

Technological characteristics

Grain protein content: Sowing dates had significant effect on grain protein content (PC) as given in Table 2. The delayed sowing progressively and significantly increased the PC. The highest PC (12.6 and 13.8%) was recorded in S_4, followed by S_3 and lowest (11.9 and 12.8%) in the S_1, but was at par with S_2. The increase in PC varied between 5.2- 7.9% in S_4 over S_1 sowing. The effect of irrigation was significant in first season and non-significant in second season. The highest PC (12.5 and 13.4%) was obtained in I_3 and lowest (12.1 and 13.0%) in I_1 irrigation regime in both the seasons. Sowing had a large effect on PC and this was probably starch deposition driven by the thermal condition prevailing during grain filling stage. This was particularly evident on comparing the S_1 and S_4 sowing. The variation in PC can also be explained by dilution effect. The increase in PC with increased temperature and delayed sowing is consistent with previous studies (Gooding *et al*., 2003; Zende *et al*., 2005, Motzo *et al*., 2007; Farooq *et al*., 2011; Singh *et al*., 2012). The highest PC in I_3 irrigation regime might be due to moisture stress has incremental effect on nitrogen accumulation per unit starch and reduction in the carbohydrates synthesis. On other hand, adequate moisture in I_1 and I_2 may decrease PC by dilution of nitrogen with carbohydrates accumulation. Our observation that the decrease in PC with increase in irrigation frequencies or soil moisture content is consistent findings of other studies (Guttieri *et al*., 2005; Waraich *et al*., 2010; Coventry *et al*., 2011b; Singh *et al*., 2012; Ram *et al*., 2013).

Wet and dry gluten content: The delay in sowing progressively increased wet gluten content (WGC) of wheat grains (Table 2). The highest WGC was found in S_4 and lowest in S_1 sowing. The WGC in S_1 and S_2 sowing was at par with each other. The highest WGC recorded in I_3 and lowest in I_1 irrigation regime in both the seasons. Delay in sowing had progressively increased dry gluten content (DGC) of wheat grains (Table 2). The highest DGC (11.1 and 11.9%) was recorded in S_4 and lowest (9.6 and 11.1%) in S_1 in both seasons. The DGC in S_1 and S_2 sowing was found at par with each other in both seasons. The DGC increased by 16.5 and 7.1% in S_4 over S_1 sowing in 2010 -11 and 2011-12, respectively. Among irrigation regimes, the highest DGC (10.6 and 11.8%) recorded in I_3 and lowest (10.0 and 11.1%) in I_1 irrigation regime. The DGC in I_2 found almost similar with I_4 irrigation regime. The increase in DGC varied between 5.7-6.4% in I_3 over I_1 irrigation regime. The wet and dry gluten content in wheat grain increased significantly with each successive delay in sowing from S_1 to S_4. The significant increase in dry gluten content can be explained by the dilution effect. The gluten content is also associated with the PC. This fact can further be verified from the significantly lower PC in S_1 and S_2. The percentage of dry gluten content was in the range of 0.8-1.7% and 5.6-6.4% in I_3 irrigation regime over I_1 in first and second season, respectively.

Sedimentation value: The effect of sowing dates and irrigation regimes on sedimentation value is given in Table 2. The effect of sowing dates on sedimentation value was significant in 2010-11 and non-significant in 2011-12. The highest sedimentation value (32.1 and 35 ml) was found in S_4, which was at par with S_3. The lowest sedimentation value (30.5 and 33.8 ml) was recorded in the S_1 in both seasons. The delay in sowing led to increase in sedimentation value in both seasons. Irrigation effects were significant on sedimentation value. The highest sedimentation value was observed in I_3 (32.08 and 35.3 ml) and lowest (31.1 and 33.8 ml) in I_1 irrigation regime. Sedimentation value of flour increased with increasing temperature as sowing delayed. Moisture stress significantly increased sedimentation value in I_3 and I_4 irrigation regime.

Coarse bran: Data in Table 2 revealed effect of sowing dates and irrigation regimes on coarse bran of wheat grain. The significantly highest values of coarse bran obtained in S_4 (30.5 and 35.9%) over lowest in S_1 (28.6 and 34.5%). Among irrigation regimes, significantly highest percentage of coarse bran was obtained in I_3 (30.4 and 36.0%) and lowest (29.0 and 34.7%) in I_1 irrigation regime.

Fine bran: Effect of sowing date and irrigation regimes on fine bran of wheat grain is shown in Table 2. The significantly highest values of fine bran obtained in S_1 (3.2%) over lowest in S_3 (2.7%) in first season. The difference between sowing dates were non-significant in second season. The significantly highest percentage of fine bran was obtained in I_4 (3.1 and 2.7%) and lowest (2.7 and 2.2%) in I_3 irrigation regime.

Conclusion

Study revealed that the November 1 and November 16 sowing, although resulting in lower protein content (11.9-13.2%) but maintains higher grain hardness (73.1-85.8), flour recovery (62.5-68.2%) and hectolitre weight (79.7-80.2 kg hl^{-1}) than other sowing dates. Irrigation scheduling at 25% MAD of ASW and 50% MAD of ASM yields optimum protein content (12.1-13.2), higher flour recovery (62.2-68.2%) and lower percentage of coarse bran (28.6-35.0%). The effect of irrigation regimes was non-significant on grain hardness, grain diameter and dry gluten content. Therefore, it may be inferred that optimum milling and technological properties of wheat grain can be maintained by sowing till mid-November and irrigation scheduling up to 50% depletion of ASM in sandy loam soils of semi-arid region.

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