Full Length Research Paper

Kernel quality and morphological traits of scented rice (cv. *Super Basmati*) in relation to irrigation and zinc application

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Two year field study was conducted at Adaptive Research Farms Sheikhupura and Sargodha with the objective to investigate the impact of irrigation water and zinc application on kernel quality and morphological traits of scented rice, and genotype Super Basmati was selected for this study. Results indicated that increasing applications of irrigation and zinc has positive influence on kernel quality and morphological characters of super basmati, and from two sites data of two growing seasons it was concluded that 14 irrigations and application of zinc at 14 kg ha^{-1} seems best to obtain optimum response in fine rice. Correlation coefficient between grain yield and morphological characteristics of aromatic rice was also studied and the data showed that grain yield was significantly and positively correlated with quality attributes at both experimental sites.

Key words: Physiochemical properties, economic yield, water treatments, fertilization, *Oryza sativa* L.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops and is staple food for more than 50% of the world's population (Fageria et al., 2008). In Pakistan it holds second position in consumption after wheat and is grown on an area of 2963 thousands hectares, with an annual production of 6952 thousand tons, having an average yield of 2346 kg ha^{-1} (GOP, 2009). The yield potential of Basmati varieties ranges from 4.5 to 6 tha^{-1} while the actual yield of Basmati varieties obtained by the farmers is 2.0 to 2.8 t ha^{-1} (Ahmad et al., 2005; Shivay et al., 2010). Water scarcity is increasing in the world (Xie et al., 2008). Adequate water supply is one of the most important factors in enhancing crop production. Sharma et al. (2008) found significant effect of pre-sowing irrigation on both the grain and straw yield and on the nutrient concentration of rice crop. Crusciol et al. (2003)

studied effects of irrigation levels on the quality and grain nutrient content of upland rice and found synergistic effects. Zinc (Zn) deficiency in rice has been reported from all over the world (Mirzavand, 2007), and is a barrier in achieving yield targets in crops particularly in rice growing areas (Shivay et al., 2008, 2010). Its deficiency causes a considerable reduction (25 to 50%) in paddy yield, so its application at proper time and quantity has a vital importance for maximizing production of rice (Ahmad et al., 2005; Hussain et al., 2005). Review of literature showed that data on the zinc and water application of Basmati rice is lacking in Pakistan, and limited information is available over their impact on quality and morphological characters of transplanted fine rice so the present study was chalked out to optimize traits under consideration in relation to water and zinc use.

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Table 1. Physical and chemical analysis of experimental soils.

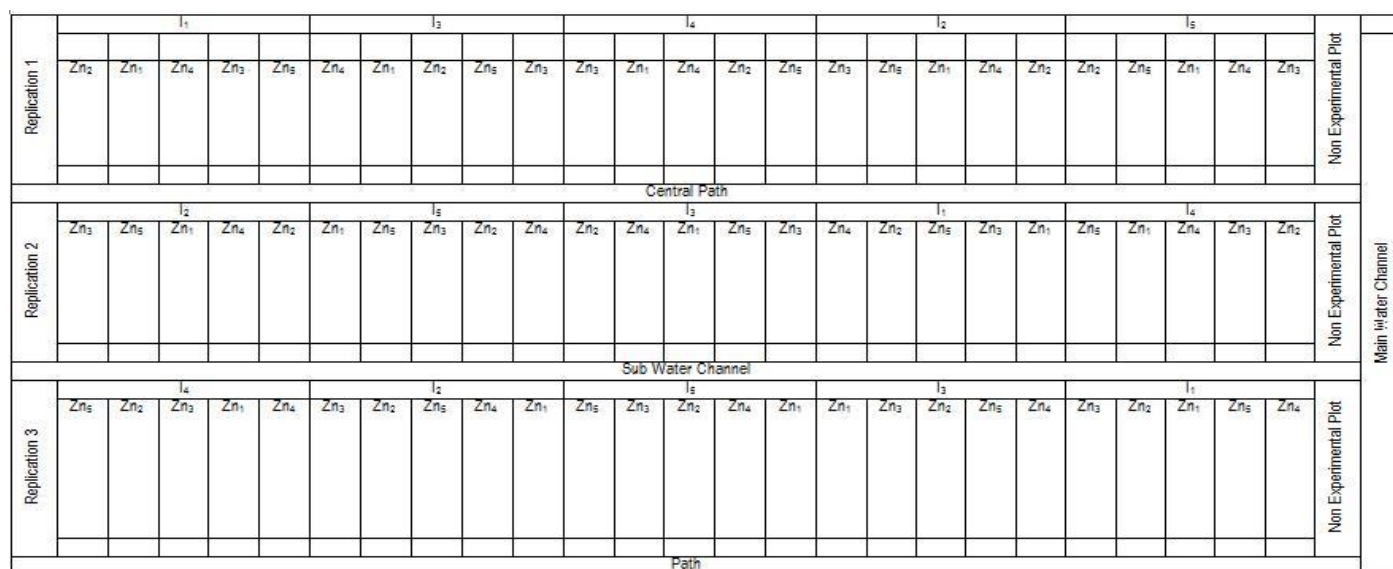| Determination	Unit	Sheikhupura	Sargodha
Physical analysis			
Sand	%	14	23
Silt	%	70	60
Clay	%	16	17
Textural class	%	Loam	Silty loam
Chemical analysis			
pH		8.40	7.60
Total soluble salt	%	10.1	15.02
Organic matter	%	0.80	0.96
Total nitrogen	%	0.07	0.06
Available phosphorus	ppm	10.4	16.80
Available potassium	ppm	204	235

Figure 1. Layout plan of experiment. Treatments: A. Irrigation levels main plot: I_1: 6; I_2: 8; I_3: 10; I_4: 12; I_5: 14. B. Zinc rates sub plot: Zn_1: 0 kg ha^{-1}; Zn_2: 8 kg ha^{-1}; Zn_3: 10 kg ha^{-1}; Zn_4: 12 kg ha^{-1}; Zn_5: 14 kg ha^{-1}; Replication: 3; Plot size: 1.8 m x 12 m; Plant to plant distance: 22.5 cm; Row to row distance: 22.5 cm; Fertilizer N:P:K: 140:80:60 kg ha^{-1};

MATERIALS AND METHODS

Location

Field studies were conducted at Adaptive Research Farm Sheikhupura (31.6°N, 74.6°E, 217 m) and Sargodha (32.04°N, 72.67°E, 188 m) over a period of two growing seasons (2009, 2010).

Soil analysis

Composite soil sample to a depth of 30 cm was obtained from the experimental area with soil auger prior to sowing of crop. The sample was analyzed for its physio-chemical properties. Percentage of sand, silt and clay was determined by Bouyoucos hydrometer method using 1% sodium hexametaphosphate as a dispersing agent. Textural class was determined using the international textural triangle (Moodie et al., 1959). Soil analysis showed that at Sargodha soil was silty loam in texture whereas in case of Sheikhupura the soil texture was loam (Table 1). The method of Homer and Pratt (1961) was used to determine various chemical properties of the experimental soil that showed that both sites had pH near 8.00. Moreover, soils of both the sites were rated as deficient in organic matter and elements like N, P, K, etc.

Design and treatments

Experiment was laid out in randomized complete block design with split arrangement replicated thrice. Treatments were five irrigation levels (I_1 = 6, I_2 = 8, I_3 = 10, I_4 = 12, I_5 = 14) in main plots and five Zn application rates (Zn_1=0 kg ha^{-1}, Zn_2=8 kg ha^{-1}, Zn_3=10 kg ha^{-1}, Zn_4=12 kg ha^{-1}, Zn_5=14 kg ha^{-1}) in sub plots. There were total 25 plots with a net plot size of 1.8 m × 12 m long with row to row and plant to plant spacing of 22.5 cm (Figure 1).

Table 2. Crop husbandry operations for the experiments at Sheikhpura and Sargodha.

Operations	Sheikhupura	Sargodha
Nursery sowing date	05.06.09/10	05.06.09/10
Cultivation (puddling)	02.07.09/10	02.07.09/10
Transplanting dates	05.07.09/10	06.07.09/10
Fertilizer [P (SSP) at 80 kg ha^{-1}]	05.07.09/10	06.07.09/10
K (SOP) at 60kg ha^{-1}	05.07.09/10	06.07.09/10
N (Urea) 140 kg ha^{-1}N$_1$	05.07.09/10	06.07.09/10
N$_2$	31.07.09/10	01.08.09/10
Crop establishment	16.07.09/10	16.07.09/10
Hand weeding	22.07.09/10	23.07.09/10
Irrigation*		
Date of sampling		
33 days after transplanting (DAT)	08.08.09/10	08.08.09/10
47 days after transplanting (DAT)	22.08.09/10	23.08.09/10
61 days after transplanting (DAT)	05.09.09/10	06.09.09/10
75 days after transplanting (DAT)	19.10.09/10	20.10.09/10
89 days after transplanting (DAT)	02.10.09/10	03.10.09/10
103 days after transplanting (DAT)	16.11.09/10	17.11.09/10
Final harvest	30.11.09/10	01.12.09/10

*A flooded condition was maintained continuously throughout the active growth period of the rice crop.

Crop husbandry

Crop was transplanted manually on respective dates on puddled field (Table 2). Recommended doses of phosphorus and potassium, that is, 80 and 60 kg ha^{-1} in the form of single super phosphate (SSP) and potassium sulphate were applied to all plots at the time of puddling before transplanting during both seasons. Nitrogen was applied in the form of urea at the rate of 140 kg ha^{-1}. Half of nitrogen fertilizer was applied to all plots at the time of puddling before transplanting and remaining half of nitrogen at 30 days after transplanting (DAT). Zinc was applied in the form of zinc sulphate and half of its dose was applied to all plots at the time of puddling before transplanting and remaining was applied at active tillering (dose as per treatments). Buffer plots were maintained to avoid seepage/border effect of irrigation among various treatments. Agronomic practices such as weeding, irrigation and plant protection measures etc. were kept normal and uniform for all the treatments.

Parameters of quality and morphological characters studied

Sterility, opaque, abortive and normal kernels

Sterile spikelets, opaque, abortive and normal kernels were counted from ten panicles from the primary tillers randomly selected from each treatment. The whole panicles were carefully sketched to differentiate between sterile spikelets, abortive, opaque and normal kernels (Nagato and Chaudhry, 1969). A common electric lamp with a flexible stand was used as a source of light. A panicle was positioned in front of the lamp so that light may pass through it in order to differentiate different stages of kernel development. Number of sterile spikelets, abortive, opaque and normal kernels from each sketch of all the treatments were counted, averaged and expressed in percent.

Kernel protein content

Protein contents of rice seed were estimated by micro Kjeldalh digestion to determine nitrogen content, which is then converted to protein by multiplying with the factor 5.9 (Jacobs, 1958).

Kernel amylose content

Milled and grounded rice seed was used for the determination of amylose content according to the method prescribed by Juliano (1971). The intensity of blue color was read in a spectronic photometer 20 (Baush and Lomb) at 620 nm.

Dimensions of kernel

Kernel dimensions (length and width) were taken on 100 normal kernels from each treatment with the help of a dial caliper.

Kernel water absorption ratio

The water absorption ratio was determined by the formula reported by Juliano et al. (1965): Water absorption ratio (WAR) = Weight of cooked rice/weight of raw rice

Statistical analysis

Data collected was analyzed statistically by employing the Fisher's analysis of variance technique on personal computer. The effect of I and Zn rates was analyzed using polynomial contrast within the analysis of variance structure. The significance of treatment means was tested using least significance difference (LSD) test at 5% probability level (Steel et al., 1997).

Table 3. Year, irrigation and zinc impact on quality and morphological parameters of super basmati at Sheikhupura (SH) and Sargodha (SG).

Treatment	Spikelet sterility (%)			Abortive kernels (%)			Opaque kernels (%)			Normal kernels (%)			Water absor	
A=Year	SH	SG	Mean	SH	SG	Mean	SH	SG	Mean	SH	SG	Mean	SH	S
2009	6.82	6.55	6.69	7.69	7.58[a]	7.64	7.05	6.87	6.96	65.31	66.39	65.85	3.36	3.0
2010	6.81	6.64	6.73	7.71	6.97[b]	7.37	6.90	6.83	6.87	66.10	65.76	65.93	3.11	2.8
LSD 5%	NS	NS		NS	0.38		NS	NS		NS	NS		NS	0.2
Sx	0.239	0.051		0.266	0.088		0.266	0.065		2.393	0.719		0.085	0.0
B=Irrigation levels														
I$_1$:6	5.98[c]	6.40[c]	6.19	6.90[d]	6.98[c]	6.94	6.25[e]	6.67[c]	6.46	61.91[e]	61.94[c]	61.93	2.88[e]	2.8
I$_2$:8	6.12[c]	6.53[c]	6.33	6.94[d]	7.00[c]	6.97	6.41[d]	6.62[c]	6.52	64.83[d]	65.87[b]	65.35	2.99[d]	'82.
I$_3$:10	6.48[b]	6.50[c]	6.49	7.49[c]	7.13[c]	7.31	6.80[c]	6.71[c]	6.76	66.37[c]	66.46[b]	66.42	3.53[a]	3.0
I$_4$:12	7.81[a]	6.69[b]	7.25	8.79[a]	7.54[b]	8.17	7.88[a]	6.99[b]	7.44	67.97[a]	68.42[a]	68.20	3.33[c]	3.0
I$_5$:14	7.68	6.86[a]	7.27	8.37[b]	7.74[a]	8.06	7.52[b]	7.26[a]	7.39	67.46[b]	67.68[a]	67.57	3.43[b]	3.0
LSD 5%	0.19	0.15		0.17	0.18		0.11	0.25		0.24	0.98		0.09	0.1
Sx	0.091	0.073		0.079	0.083		0.050	0.118		0.113	0.461		0.044	0.0
C=Zinc application rate(kg/ha)														
Zn$_1$:0	6.61[c]	6.71[a]	6.66	7.44[d]	7.21[b]	7.33	6.43[e]	6.98[a]	6.71	62.76[e]	60.87[e]	61.82	2.98[e]	2.6
Zn$_2$:8	6.72[b]	6.61[ab]	6.67	7.58[c]	7.22[ab]	7.40	6.81[d]	6.93[ab]	6.87	64.79[d]	64.77[d]	64.78	3.14[d]	2.8
Zn$_3$:10	6.88[a]	6.56[b]	6.72	7.78[b]	7.30[ab]	7.54	7.11[c]	6.85[bc]	6.98	65.85[c]	66.43[c]	66.14	3.24[c]	3.0
Zn$_4$:12	6.91[a]	6.58[b]	6.75	7.82[ab]	7.33[a]	7.58	7.20[b]	6.78[cd]	6.98	66.96[b]	68.30[b]	67.63	3.33[b]	3.0
Zn$_5$:14	6.97[a]	6.51[b]	6.75	7.88[a]	7.31[ab]	7.60	7.30[a]	6.70[d]	6.99	68.18[a]	70.00[a]	69.09	3.47[a]	3.1
LSD 5%	0.11	0.10		0.08	0.10		0.09	0.12		0.35	0.28		0.07	0.0
Sx	0.053	0.049		0.038	0.052		0.044	0.062		0.177	0.558		0.038	0.0
Interaction (BXC)	**	**		**	**		**	**		**	**		**	**

Means sharing different letters differ significantly at P < (0.05); *, **: Significant at 0.05 and 0.01, respectively; NS: Non-significant; S$\bar{x}$= Standard error of me

RESULTS

Spikelet sterility

There were non-significant differences regarding spikelet sterility between years at Sheikhupura and Sargodha sites. Increasing rates of irrigation application significantly and linearly increased spikelet sterility. Zinc application rate also followed a similar trend regarding spikelet sterility to that of irrigation application rate at Sheikhupura site, but differentially affected it at Sargodha (Table 3).

Abortive kernels

Table 3 showed year effect on abortive kernels was non-significant at Sheikhupura but significant at Sargodha. Th the percentage among different abortive kerne irrigation applic treatment at Sh significantly at l Whereas at Sa increased with

also showed that increasing rate of Zn application significantly increased percentage of abortive kernels at both sites.

Opaque kernels

The year effect on percentage of opaque kernels was found to be non-significant at both sites. Data showed that I_4 significantly increased the percentage of opaque kernels compared to other rates of irrigation application at Sheikhupura. At Sargodha I_5 increased the percentage of opaque kernels. Zn application rates showed differential but significant effect on percentage of opaque kernels at both sites (Table 3).

Normal kernels

The percentage of normal kernels was non-significant between the two cropping years. There were significant effects of irrigation application rates on the percentage of normal kernels, it increased upto I_4 (12 irrigations) and I_5 (14 irrigations) at Sheikhupura and Sargodha sites, respectively. Differences in normal kernels between I_4 and I_5 treatments at Sargodha were, however, non-significant. At both sites, increasing rates of Zn application also significantly and linearly affected the percentage of normal kernels (Table 3).

Water absorption ratio

Table 3 showed that year effect on water absorption ratio was significant at Sargodha but not at Sheikhupura. The increasing rate of irrigation levels significantly increased water absorption ratio up to I_3 (10 irrigations) at Sheikhupura; thereafter it significantly decreased at I_4 or I_5 irrigation treatments. Whereas, at Sargodha site increasing level of irrigation increased water absorption ratio but the difference were non-significant. Data also showed that increasing rate of Zn application significantly and linearly increased water absorption ratio compared to control.

Kernel length

Table 4 showed that year effect on kernel length was only significant at Sargodha where kernel length was 9.0% higher in 2009 than 2010. Increasing rate of irrigation levels significantly increased kernel length at both sites, and this response was quadratic and linear at Sheikhupura and Sargodha, respectively. At both sites, increasing rates of Zn application significantly increased the kernel length and this response was linear in nature.

Kernel width

The year effect on kernel width was significant at Sheikhupura (Table 4). Increasing rate of irrigation levels significantly increased kernel width and this response was quadratic and linear in nature at Sheikhupura and Sargodha sites, respectively. The increasing rate of Zn application significantly and linearly affected kernel width compared to control at both sites.

Kernel protein contents

Table 4 showed that kernel protein contents were non-significant in two cropping seasons. Increasing rates of irrigation levels significantly increased kernel protein contents compared to control at both sites. Differences between I_3, I_4 and I_5 treatments were, however, statistically at par at both locations. At both sites, increasing rate of Zn application significantly and linearly enhanced kernel protein contents up to Zn_5 (14 kg ha^{-1}) treatments; differences between Zn_3 and Zn_4 treatments were, however, statistically at par.

Kernel amylose contents

Year effect on kernel amylose contents was found to be non-significant at both sites. Increasing rate of irrigation levels significantly enhanced kernel amylose contents upto I_3 treatment at both sites; thereafter it significantly decreased at I_5 treatment at Sargodha site. At Sheikhupura, differences between I_3, I_4 and I_5 treatments were, however, statistically at par regarding kernel amylose contents. Table 4 also showed significant differences in kernel amylose contents among different rates of Zn application. At both sites, kernel amylose contents were significantly and linearly increased with increasing Zn application rates.

Relationship between grain yield and morphological characters

Data in Table 5 showed that grain yield was significantly and positively correlated with spikelet sterility, abortive, opaque and normal kernels at Sheikhupura site. The kernel length was not correlated with grain yield. Both grain yield and protein and amylose contents were also positively correlated at Sheikhupura site. At Sargodha site, non-significant correlation was observed between grain yield and spikelet sterility, opaque kernels, and amylose contents. Whereas normal kernels, kernel length and kernel width were positively and significantly correlated with grain yield. Both water absorption ratio and protein contents were also positively correlated with the grain yield. The pooled data showed positive and

Table 4. Year, irrigation and zinc impact on quality and morphological parameters of super basmati at Sheikhupura (SH) and Sargodha (SG).

Treatment	Kernel length (mm)			Kernel width (mm)			Kernel protein content (%)			Kernel amylose content		
A=Year	SH	SG	Mean	SH	SG	Mean	SH	SG	Mean	SH	SG	Me
2009	7.50	7.22^a	7.36	2.52^a	1.77	2.15	8.62	8.48	8.55	22.54	22.44	22
2010	6.89	6.62^b	6.76	1.91^b	1.73	1.82	8.34	8.31	8.33	22.09	22.31	22
LSD 5%	NS	0.47		0.17	NS		NS	NS		NS	NS	
	0.277	0.109		0.040	0.019		0.306	0.151		0.711	0.161	
B=Irrigation levels												
I$_1$:6	6.43^e	6.33^d	6.38	1.67^d	1.62^c	1.65	8.02^c	8.06^b	8.04	21.73^b	22.84^c	21
I$_2$:8	6.65^d	6.58^c	6.62	1.70^d	1.66^b	1.68	8.23^b	8.24^b	8.24	21.95^b	22.48^b	22
I$_3$:10	7.07^c	6.90^b	6.99	2.13^c	1.67^b	1.90	8.75^a	8.54^a	8.65	22.50^a	22.75^a	22
I$_4$:12	8.15^a	7.32^a	7.74	3.03^a	1.89^a	2.46	8.65^a	8.64^a	8.65	22.93^a	22.49^b	22
I$_5$:14	7.68^b	7.43^a	7.56	2.56^b	1.91^a	2.24	8.73^a	8.49^a	8.61	22.48^a	22.30^b	22
LSD 5%	0.1	0.17		0.09	0.03		0.18	0.23		0.47	0.21	
	0.045	0.08		0.043	0.015		0.084	0.107		0.222	0.099	
C=Zinc application rate(kg/ha)												
Zn$_1$:0	6.52^e	6.47^e	6.50	2.00^c	1.66^d	1.88	8.08^d	7.09^d	7.59	21.70^d	21.83^d	21
Zn$_2$:8	7.04^d	6.78^d	6.91	2.07^c	1.71^c	1.89	8.30^c	8.33^c	8.32	22.10^c	22.35^c	22
Zn$_3$:10	7.35^c	6.97^c	7.16	2.26^b	1.76^b	2.01	8.59^b	8.51^b	8.55	22.44^b	22.43^{bc}	22
Zn$_4$:12	7.48^b	7.15^b	7.32	2.34^a	1.81^a	2.08	8.62^b	8.55^{ab}	8.59	22.58^{ab}	22.54^b	22
Zn$_5$:14	7.60^a	7.25^a	7.43	2.41^a	1.83^a	2.12	8.79^a	8.60^a	8.70	22.76^a	22.70^a	22
LSD 5%	0.06	0.07		0.08	0.03		0.10	0.09		0.18	0.14	
	0.031	0.036		0.038	0.013		0.049	0.047		0.091	0.069	
Interaction(BXC)	**	**		**	**		**	**		**	**	

Means sharing different letters differ significantly at P < (0.05); *, **: Significant at 0.05 and 0.01, respectively; NS: Non-significant; S$\bar{x}$= Standard error of me

significant correlation of yield with all the morphological characteristics.

DISCUSSION

From the kernel quality point of view, increasing levels of irrigation and Zn application rates produced the maximum length of kernel in super Basmati. The I$_5$Zn$_5$ treatment combination increased the plant height and positively influenced most yield attributes in super Basmati rice and finally resulted in increased rice yield. It is known that Zn concentration and uptake by rice also increased with the level of Zn application. Such a response of rice on such soils was expected as reported by

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Table 5. Correlation coefficient between grain yield and morphological characteristics of aromatic rice.

Character	Sheikhupura	Sargodha	Pooled
Grain yield vs. spikelet sterility	0.973**	0.418[NS]	0.898**
Grain yield vs. abortive kernels	0.732**	0.663*	0.859**
Grain yield vs. opaque kernels	0.971**	0.342[NS]	0.871**
Grain yield vs. normal kernels	0.855**	0.815**	0.834**
Grain yield vs. kernel length	-0.373[NS]	0.812**	0.913**
Grain yield vs. kernel width	0.929**	0.821**	0.923**
Grain yield vs. water absorption ratio	0.708**	0.646*	0.713**
Grain yield vs. kernel protein contents	0.775**	0.623*	0.686*
Grain yield vs. kernel amylose contents	0.833**	0.039[NS]	0.766**

*, ** Significant at 5 and 1% level; [ns]non-significant.

of normal kernels with the increasing rate of irrigation and Zn levels may be due to adequate supply of irrigation and Zn that enhanced the availability of other nutrients like N, P and K, and partly due to low competition among plants. Thus kernels under these conditions developed in the absence of any water stress or nutritional stress (Ahmad et al., 2009; Khan et al., 2009; Shivay et al., 2010). Iqbal (2004) found that yield of rice increased 50 to 60% in response to the application of N, P interaction with water. Results reported also showed that under normal conditions the kernel length and width increased over lower rates of irrigation and Zn application by 8 to 10 times. Shivay et al. (2005) concluded that Zn fertilization had no deleterious effects on the quality of Basmati rice; it even increased hulling percentage and producing longer and better grains.

Conclusion

Super basmati fine rice kernel quality and morphological traits were significantly impacted by irrigation and zinc application. Increasing rates of irrigation and zinc applications showed significant effects on spikelet sterility, percentage of abortive and opaque kernels at both the sites. The percentage of normal kernels was also significantly increased. Kernel dimensions such as length and width were also significantly affected by the increasing rates of treatments. At both sites, increasing rates of I and Zn significantly increased kernel protein and amylose contents compared to control or lower rates of I and Zn treatments.

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