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Stability Analysis for Seed Yield and Related Traits of Oat (*Avena sativa* L.) under Varied Conditions of North-Western Himalayas

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was undertaken to determine the stability of oat genotypes for seed yield under different environmental conditions prevalent in north- western Himalayas. One hundred and twenty-one genotypes including five checks were evaluated in simple lattice design for three years (Rabi 2015-16 to 2017-18). The stability was estimated using Eberhart and Russell model for six traits viz., days to 50% flowering, days to 75% maturity, biological yield per plant, harvest index (%), 1000-seed weight (g) and seed yield per plant (g). The pooled analysis of variance showed that genotypes behaved differently for all the traits over the environments. The most stable performing genotypes identified were S8-217, UPO-119, Oats-17 and Oats-8655, respectively. However, the best performing and stable genotypes for seed yield were JPO-24 and Oat- 79. Thus, the genotypes identified as stable and well adapted over test environments could be exploited as valuable gene pool in further breeding programme, for developing stable genotypes with high yield potential or could be tested in multi-locational trials to release as a cultivar.

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1. INTRODUCTION

"Oat, a cereal crop is originated from Mediterranean regions" [1]. "It is preferred as a grain crop in Central and Western Europe and as fodder in Asia Minor since Christian era" [2]. "As an economically important crop it ranks sixth in world cereal production after wheat, maize, rice, barley and sorghum. Its seed has a high nutritional value with a high content of essential minerals, unsaturated fatty acids, galacto-lipids and the globular proteins amongst any cereal crop. The mixed β-D-glucans present in high levels helps in digestion and have cholesterol-lowering properties. Moreover, the compounds such as tocopherols, inositol phosphates and avenanthramides present in it possess antioxidative properties" [3]. Oat is generally grown in India for fodder purposes. But at present, its importance as grain has been felt because of the above benefits and efforts are now being made to develop oat varieties for dual purpose, i.e., higher fodder yield as well as higher grain yield [4].

In India, oat is mainly cultivated in Himalayan states have a wider adaptability like in Kashmir, Himachal Pradesh and Uttarakhand because of excellent growth habitat, fast re-growth, better nutritional status, low water requiring and cold tolerance ability. The Himalayan region is known for its diverse and unpredictable climatic conditions due to complex topography and change in the altitude.

"One of the main issues to be considered in plant breeding programs is the evaluation of new cultivars for seed yield and quality under different environments or seasons. The suitability of a variety over varied environments is usually examined by the degree of its interaction with different environments under which it is planted. The genotype x environment interactions could be due to macro-environmental conditions (predictable effects) or by climatic and micro-environmental conditions (non-predictable effects)" [5]. "A variety is considered to be more stable if it has a high mean yield with low degree of fluctuation in yield potential for growing over different locations or seasons" [6].

Among various stability models the most widely used is Eberhart and Russell model [7] model that has been followed to interpret the stability statistics in various crops. In this model the regression coefficient (bi) and deviation from regression (S^2di) are considered as two parameters for measuring the phenotypic stability of a variety. Among the predictable genotypes, phenotypic regression (bi) was tested against unity. The genotypes with bi = l were categorised as average responsive; with bi > 1 as above average responsive; and with bi < 1 as below average responsive, thus according to Eberhart and Russell [7], an ideal genotype for all the environments would be the one with bi = 1, low deviation from regression (S^2di = 0) and high mean performance; whereas the genotypes having high mean performance, S^2di = 0 and bi ± 1, would be suitable for specific environments. Thus, this study was undertaken to identify the best performing and stable genotypes of oat under different climatic conditions of N-W Himalayas for seed yield.

2. MATERIALS AND METHODS

The experiment was undertaken during three cropping seasons from *rabi* 2015-16 to 2017-18 at CSK HPKV, Palampur situated at 32°6' N latitude, 76°3' E longitude with an elevation of 1290.8 m (a.m.s.l). This location agro-climatically is the mid-hill zone of Himachal Pradesh (Zone-II), classified by humid sub-temperate climate with high precipitation (2500 mm). The mean weather data i.e., temperature (˚C), rainfall (mm) and relative humidity (%) are given in Fig. 1. The soil pH ranging from 5.0 to 5.6 confirms its acidic nature and texture is silty clay loam. The material comprising 121 oat germplasm lines with five checks *viz.,* Palampur-1, RO-19, Kent, OS-6 and UPO-212 were experimented with two replications using simple lattice design. Each genotype was grown in two rows of 1m length with plant-to-plant distance of 5 cm and row to row distance of 25cm. The plot size was 1.0 x 0.5 m^2. The data was recorded in each replication on five randomly selected plants on six agromorphological traits *viz.,* days to 50% flowering, days to 75% maturity, biological yield per plant, harvest index (%), 1000- seed weight and seed yield per plant (g). The analysis of the data was carried out using standard statistical programmes. The linear regression model [7] was used to evaluate the genotypes for their stability and two stability parameters were calculated i.e., regression coefficient (bi) and mean squared deviation from linear regression (S^2di).

$$Yij= \mu i + bi\ Ij + \delta ij$$

Where,

> Yij = mean performance of the i th genotype in the jth environment
> μi = mean yield of i th genotype over all the environments
> bi = regression coefficient of the ith genotype to varying environments
> Ij = environmental index, i.e. mean of all the genotypes at the jth environment minus the grand mean
> δij = deviation from regression the ith genotype in the jth environment.

3. RESULTS AND DISCUSSION

3.1 Significance of Mean Squares

The pooled analysis of variance (Table 1) showed significant mean sum of squares for the genotypes and environments for all the traits, which revealed that genotypes performed differently with respect to each trait among varying environments. The extent of variation for G × E interaction was significant for seed yield per plant and E + (G × E) for all the characters except biological yield and 1000-seed weight, which depicted that the genotypes showed strong interactions with the environments for these traits. Mean sum of squares for environment (linear) was significant for all the traits. Also, the extent of variance due to genotypes and environments was higher than that of genotype x environment interaction for all the characters. Further the higher mean sum of squares due to the linear component of genotype × environment than the non-linear component of G × E signified the major differences among the environments contributed for maximum part of overall variation for all the characters studied which is mainly caused by variation in weather conditions during different growing seasons and hence, the genetic expression for seed yield could be predicted across the environments.

Variance due to G× E (linear) was significant for seed yield per plant (g), days to 75% maturity, harvest index and days to 50% flowering which depicted linear regression to be the major component for differences in stability and performance for these traits can be depicted with some credence under varying environments. Likewise, the significant variation due to non-linear genotype x environment component revealed that the deviation from linear regression line have also played a significant role towards variation in genotypic stability for days to flowering, days to maturity, biological yield and harvest index. Thus, both predictable and unpredictable components contributed significantly to genotype x environment interactions for these traits, with predominance of the former component, suggested that genotypic performance can be done with greater precision across environments. Similar results were reported by Kebede et al. [8]; Howarth et al. [9]; Singh et al. [10]; Doehlert et al. [11]. The non-significance of linear against non linear mean square component for biological yield per plant and 1000-seed weight indicated that the reliable prediction of G× E interaction are not feasible. However, prediction could be done for individual traits based on stability parameters even if they are unpredictable [12].

3.2 Stability Analysis

The parameters of stability (mean, b_i &S^2_{di}) for all the characters were computed (Supplementary Table 1). The phenotypic stability of a genotype is measured by three parameters *viz.,* (μi), bi and S^2di according to Eberhart and Russell [7]. The regression coefficient i.e. phenotypic regression (bi) was taken as a parameter for responsiveness to change in the environment and S^2di was used as the parameter for stability. However, the significance of the coefficient of regression (b_i) means responsiveness either to favorable environment (b_i>1) or poor ones (b_i<1).

The average values ranged from 131-157 days with average value of 144 for days to 50% flowering (Supplementary Table 1). Considering the genotypes showing average performance, S8-217 (133 d), JHO-813 (135 d), OL-9 (137 d) and UPO-102 (138 d) showed stable performance over all the environments and based on significant values of regression coefficients (b_i>1), the genotypes found suitable for favourable environments having less resistance to environmental changes were OS-9, JPO-25 and JPO-17.

Days to 75% maturity ranged from 167-184 days with an average value of 175 days (Supplementary Table 1). Genotypes UPO-119, IG-03-48, PO-1, JPO-20, KRR-AK-06, OL-125, Oat-8655 and JHO-813 with the mean performance of 168, 170, 171, 171, 171, 172, 173 and 173 days, respectively were found to be stable while, the most responsive genotypes for favourable conditions were JPO-19, SKO-28, KRR-AK-15. Regarding biological yield per plant, the mean values ranged from 72.00-130.21 with average value of 100.86 g. Genotypes, Oat-17 and IG-03-211 with mean value of 115.71 and 106.71 g were found suitable and stable as b_i values equals to unity with non-significant S^2_{di} values. The most responsive genotypes JPO-41 and OS-6 were observed performing better under suitable climatic conditions for this character. For harvest index, the mean varied from 15.72-31.96 % with average value of 23.19 %. The genotypes, Oat-8655 (25.59 %), OS-92 (25.45 %), EC-528889 (24.7 %), UPO-119 (24.45 %), JPO-24 (24.11 %), JPO-45 (24.06 %), HFO-52 (24.05 %) and OG-77 (23.58 %) were observed to be suitable and stable across the environments. In case of 1000-seed weight, mean values ranged from 21.53-44.52 with average value of 32.94 g and IG-03-251 (41.72 g), OG-77 (34.14 g), ADG-96 (34.07 g) and KUE (33.94 g) genotypes were found stable and suitable over all the environments. Based on bi and S^2_{di} parameters, the most responsive genotypes were UPO-130, JPO-30 & OS-9 for harvest index and EC-528890 and EC-558905 for 1000-seed weight (Table 2). So far seed yield per plant is concerned, the mean varied from 14.63-32.75 with average value of 23.06 g and only two genotypes, JPO-24 (27.75g) and Oat-79 (24.49 g) were found suitable and stable across the environments. Two genotypes, JPO-3 and IG-03-208 showed significant bi values (bi> 1), which indicates specific adaptation to congenial climatic conditions and a little bit change in environment will result in a major change in genotypic response. Thus, the findings revealed sufficient variation in the genotypic performance across varied environmental conditions. Similar results were obtained by Lorencetti et al. [13]; Altaf et al*.* [14]; Akcura et al. [15]; Singh et al. [10]; Howarth et al*.* [9] in oats and Bouchareb and Guendouz [16]; Hussain et al. [17] in bread wheat where the genotypes behaved differently with the changing environments, concluding the presence of genetic variation among the different genotypes.

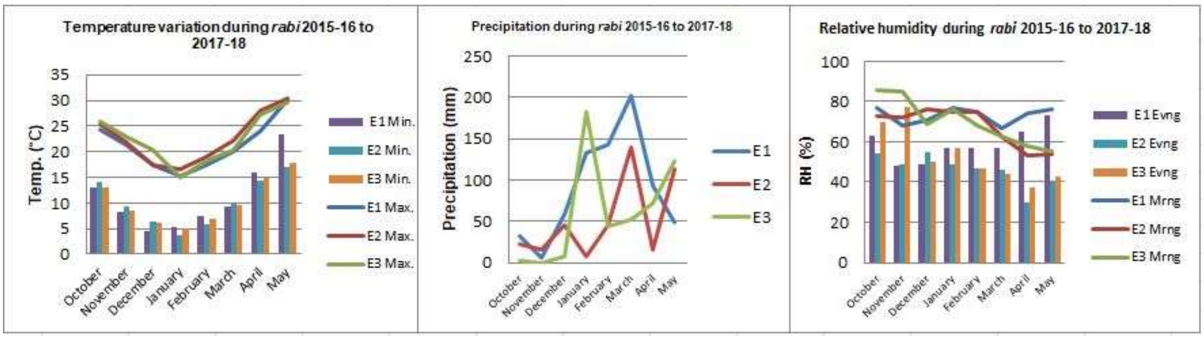

Fig. 1. Mean monthly meteorological data at Palampur [October to May for each *rabi* season 2015-16 (E1), 2016-17 (E2) and 2017-18 (E3)]

Table 1. Concurrent regression analysis of variance for seed yield and related traits over environments

Source of variation	d.f	Days to 50% flowering	Days to 75% maturity	Biological yield per plant (g)	Harvest index (%)	1000-seed weight (g)	Seed yield per plant (g)
Genotypes	120	142.69*	44.73*	379.96*	23.11*	84.36*	29.28*
Environments	2	1197.19*	5239.24*	3241.59*	520.05*	134.37*	210.22*
G ×E	240	21.27	12.03	204.3	12.57	10.57	12.60*
Environments + G ×E	242	30.99*	55.23*	229.4	16.77*	11.6	14.23*
Environment (linear)	1	2394.38*	10478.48*	6483.19*	1040.10*	268.73*	420.43*
G ×E (linear)	120	23.83*	13.36*	183.61	12.58*	10.42	17.61*
Pooled Deviation (non-linear)	121	18.55*	12.60*	223.13*	12.46*	10.64	7.52
Pooled error	360	5.43	6.19	50.18	5.05	8.9	6.28

**Significant at 5% level of probability*

Table 2. Distribution of oat genotypes on the basis of performance, responsiveness and stability for different traits

Traits	Performance		Responsiveness		High mean, unit regression and non-significant deviation from regression
	Best performing	Poor performing	Most responsive	Least responsive	
Days to 50% flowering	UPO-119	EC-528894	OS-9, JPO-25, JPO-17	SNTM-90, JPO-38	S8-217, JHO-813, OL-9 and UPO-102
Days to 75% maturity	EC-605837	EC-528894	JPO-19, SKO-28, KRR-AK-15	EC-528913, JPO-10	UPO-119, IG-03-48, PO-1, JPO-20, KRR-AK-06, OL-125, Oat-8655 and JHO-813
Biological yield per plant (g)	EC-528865	UPO-212	JPO-41, OS-6	JHO-862, SK-150	Oat-17 and IG-03-211
Harvest index(%)	JHO-99-2	JPO-29	UPO-130, JPO-30, OS-9	JPO-8, EC-528894	Oat-8655, OS-92, EC-528889, UPO-119, JPO-24, JPO-45, HFO-52 and OG-77
1000-seed weight(g)	HFO-52	JPO-19	EC-528890, EC-558905	UPO-30	IG-03-251, OG-77, ADG-96 and KUE
Seed yield per plant (g)	EC-528865	OS-9	JPO-3, IG-03-208	99-1, OL-9	JPO-24 and Oat- 79

4. CONCLUSION

The combined analysis of variance revealed significant variation for genetic characteristics and environments where the study was conducted. Genotypes JPO-24 and Oat-79 were found suitable and stable across the environments for seed yield per plant. However, genotypes JPO-3 and IG-03-208 were most responsive among all the genotypes under rich environments and genotypes 99-1 and OL-9 were least responsive and suitable for poor environments. Hence, these genotypes can be tested at multiple locations to release as a variety which is suitable for north-western Himalayan conditions or may be incorporated in breeding programmes aimed at developing high yielding and stable genotypes for a specific environmental condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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SUPPLEMENTARY TABLE

Supplementary Table 1. Estimates of stability parameters for seed yield and related traits in oat

Genotypes	Days to 50% flowering			Days to 75% maturity			Biological yield per plant(g)			Harvest index(%)			1000-seed weight (g)			Seed yield per plant (g)		
	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di
99-1	134	0.57	-5.28	170	0.80	-1.60	105.25	0.60	83.64	24.23	-2.25	23.53*	38.06	4.64	-4.82	25.15	-3.54*	-6.47
ADG-214	134	-0.04	19.18*	172	0.79	74.45	102.96	2.19*	-50.41	22.26	1.02	-2.02	31.57	3.81	-9.58	22.75	-0.02	-6.70
ADG-96	141	2.41**	-5.43	172	0.70	4.61	103.11	0.31	167.70*	24.95	1.81	-5.15	34.07	0.87	-7.80	25.70	3.98	-6.19
AVE-3018	156	1.39	7.00	184	1.21	5.55	112.14	-0.15	97.77	22.88	1.1	3.18	33.56	0.37	-6.56	25.45	1.43	-6.61
Chorripatli	138	-1.16	69.17**	171	0.75	-6.36	86.08	-1.20	-16.79	26.49	0.46	13.73	31.66	0.33	-7.38	22.62	1.39	-6.62
EC-523890	139	1.35	-3.39	171	0.48	70.85	82.67	2.25	531.15**	28.49	3.44	1.62	34.50	-0.89	-1.51	22.43	0.02	-6.70
EC-528865	139	1.97	2.73	173	0.82*	-7.50	130.21	2.67	-44.56	25.44	1.86	-5.16	38.75	0.00	-0.61	32.75	1.82	-5.42
EC-528883	147	2.18	22.06*	178	1.03	29.22	103.32	-1.30	234.28*	21.66	2.15	0.2	31.37	0.19	-9.69	22.79	5.99	-5.63
EC-528889	145	1.42	27.54*	174	0.89	1.57	109.95	-2.11	1185.73**	24.70	0.97	-5.05	39.68	0.003	-10.83	27.42	6.46	-5.47
EC-528890	145	1.37	2.54	175	0.90	4.14	104.42	0.05	-25.81	22.14	1.78	0.47	32.38	1.20*	-10.82	23.14	2.79	-6.43
EC-528894	157	2.47	28.19*	184	1.70	43.93	124.38	3.85	29.87	16.13	-0.64**	-5.39	28.89	0.23	-9.20	20.38	-2.95	10.81
EC-528895	153	2.32	25.05*	178	0.97	-5.18	126.95	1.47*	-50.69	19.49	1.09	-5.3	28.69	0.06	-10.70	24.60	1.12	-6.64
EC-528896	151	1.41	30.68*	179	1.56	-5.95	116.37	1.80	782.68**	21.80	1.46	-0.21	32.75	0.74	1.70	24.87	-0.49**	-6.71
EC-528897	154	0.86	34.28**	180	0.92	7.94	95.53	-1.43	3174.35**	20.77	-1.02	-2.56	31.54	0.13	-10.26	19.65	4.74	55.48**
EC-528898	151	2.75	-4.42	179	0.98	1.53	109.49	1.33	83.22	23.27	1.01	-1.35	28.35	0.22	-9.33	25.40	1.46	-6.61
EC-528903	147	3.13	-1.31	174	0.90*	-7.55	103.79	2.84	606.22**	21.12	1.76	-4.57	30.28	0.84	-9.67	21.36	-0.96*	-6.70
EC-528905	142	2.06	-4.89	175	1.64	-5.55	102.17	0.28	2.06	20.26	0.85	-4.16	34.42	6.78	10.37	20.71	0.71	-6.35
EC-528913	148	0.51	-1.98	173	0.47*	-7.46	95.08	1.16	221.62*	23.35	1.05	-1.72	23.98	0.40	-5.81	21.79	-0.44**	-6.71
EC-558905	135	-1.01	17.61*	169	1.06	0.08	96.67	-0.06	-21.61	21.91	2.16	4.11	40.41	1.05*	-10.83	21.15	1.68	27.83*
EC-605831	155	2.91	98.44**	177	1.99	1.21	101.08	0.57	-1.01	20.51	0.44	-4.42	26.58	0.59	1.39	20.76	0.82*	-6.70
EC-605832	145	0.05	5.00	173	0.73	19.84	95.08	-2.13	1089.85**	29.58	-1.96	27.07*	31.32	1.26	76.89**	27.06	2.39	-6.50
EC-605834	141	1.09	11.73	172	0.83	-0.18	99.68	1.94	54.85	22.44	1.24	3.89	37.01	1.50	8.91	22.10	1.05	-6.18
EC-605837	134	-0.69**	-5.45	167	0.59*	-7.48	112.28	4.10	-5.96	21.89	1.83	0.24	28.33	0.54	-8.95	24.05	-0.62	-6.66
EC-605838	144	2.53*	-5.37	176	0.90**	-7.55	103.00	2.55	416.35**	22.74	2.23	-4.79	23.30	0.90	-9.70	22.83	-0.38**	-6.71
EC-605839	141	0.69	23.21*	169	0.82	-4.86	91.38	-1.71	149.17*	23.90	1.03	-1.85	33.35	-0.36	-8.99	21.99	4.13	-6.16
Fragrati	151	1.05	8.76	177	1.33	-3.04	96.04	1.28	-47.94	18.43	-0.24	-3.88	28.64	0.56	-10.48	17.56	-1.20*	-6.69
H-B-8	147	0.83	18.55*	174	1.03	-6.52	109.91	1.27	-26.56	23.21	0.88*	-5.36	29.00	-4.15	-7.41	25.40	0.15	-6.70
HFO-102	143	2.99	-3.90	176	0.99	9.14	91.50	-1.81	3.41	22.98	1.93	44.91**	28.94	-0.80	-5.20	20.66	4.29	-6.12
HFO-114	136	-0.76	1.03	174	0.65	-2.97	107.17	3.14	-46.52	22.89	1.61	-3.36	41.49	1.52	-0.83	24.04	0.51	-6.30
HFO-163	137	0.34	1.72	169	0.64	-2.39	97.08	-2.75	59.67	23.83	1.02	5.04	27.63	0.40	-5.78	22.84	2.47	15.39
HFO-52	137	0.29	0.00	173	0.74**	-7.55	108.83	-0.74	0.98	24.05	0.86	-4.19	44.52	9.67	89.04**	26.05	2.86	-6.42
HJ-8	137	0.51**	-5.44	173	0.88	-7.04	97.63	0.71	15.59	21.98	2.19	-5.13	33.18	-0.84	-3.31	21.38	3.47	-6.31
IG-03-203	143	1.16	4.26	170	0.51	37.47	99.96	2.56	103.20	21.42	1.8	-3.72	39.81	-1.04	22.52	21.02	-0.39	-5.71
IG-03-205	137	0.53	-4.84	171	1.09	-5.10	103.79	3.92	179.80*	24.08	2.08	-3.47	37.28	1.85	-7.90	24.28	-1.28*	-6.69

Genotypes	Days to 50% flowering			Days to 75% maturity			Biological yield per plant(g)			Harvest index(%)			1000-seed weight (g)			Seed yield per plant (g)		
	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di
IG-03-208	152	1.99	23.09*	177	0.85	20.10	90.66	4.13	330.73**	20.40	2.08	19.61*	27.89	-0.88	-7.75	17.63	1.27*	-6.70
IG-03-211	147	2.28	-3.96	174	1.33	54.86	106.71	0.96	-40.08	23.78	2.47	-2.07	30.58	0.92	-10.67	25.19	3.23	-6.35
IG-03-213	147	0.52	15.29	174	1.04	21.96	83.29	0.94	147.54*	25.37	-0.12	15.12	32.94	2.74	-9.34	20.89	0.15	-6.70
IG-03-214	150	0.96	-1.68	178	1.19	10.88	101.42	1.13	-35.35	22.56	0.81	-3.93	31.55	3.52	-5.34	22.75	0.63	-6.67
IG-03-216	132	0.09	-2.11	170	0.65	-7.11	85.50	2.21	247.46*	25.24	-0.17	-5.34	39.71	3.37	34.60*	21.58	-3.36	-5.50
IG-03-246	139	1.73	1.88	178	1.33*	-7.49	94.92	-0.18	1115.20**	26.16	0.54	42.25**	33.48	-3.81	-4.00	24.08	-1.22*	-6.69
IG-03-247	137	-0.29	-3.95	171	0.89	-4.34	100.56	-1.59	65.98	23.75	1.67	30.91**	32.06	-1.60	-9.92	23.57	3.70	-6.26
IG-03-250	142	-0.66	9.91	170	0.80	49.97	92.25	-0.72	-20.16	24.66	1.05	5.69	29.24	0.22	-4.56	22.58	1.99	-6.55
IG-03-251	141	-1.01	105.05**	173	0.72	-6.45	101.92	-2.72	193.17*	26.99	-0.21	57.29**	41.72	0.91	15.00	26.81	1.25	-6.63
IG-03-254	139	1.44	5.19	175	1.09	18.62	100.38	1.94	88.27	21.72	1.03*	-5.38	38.10	2.09	-1.87	21.57	-0.64**	-6.71
IG-03-48	142	0.21	10.81	171	0.91	11.24	79.75	-0.09	-46.99	22.10	1.03	-2.5	32.15	0.66	-1.52	17.56	1.34	-6.62
IGO-14	137	-0.54	32.04**	170	0.59	1.84	106.92	0.89	185.94*	23.43	0.87	-5.04	34.32	-0.47	-2.36	24.97	-0.63	-5.80
JH0-862	137	1.40	2.88	173	0.86*	-7.43	101.82	-2.97	91.83	24.31	-0.05	116.78**	41.78	0.36	1.57	24.08	2.85	2.15
JHO-813	135	0.64	-3.38	173	0.97	3.14	105.00	3.88	90.35	23.71	1.62	-1.07	42.21	3.45	-6.77	24.51	-1.55*	-6.68
JHO-822	134	-0.15	-1.22	172	0.87	-6.30	97.45	1.24	-50.22	23.01	1.03	15.31	39.58	1.14	-4.94	22.30	-0.26	5.70
JHO-99-2	135	-0.53	-4.84	172	0.72	-6.45	89.21	-0.77	-9.76	31.96	-2.34	3.18	38.65	2.82	-1.45	28.11	-1.90*	-6.66
JPO-10	152	1.25	19.86*	178	0.47*	-7.46	126.70	-1.11	266.55*	24.16	2.38	-0.17	30.67	0.20	-9.54	31.08	7.38	-5.11
JPO-13	149	0.84	-5.38	180	1.47	-3.89	93.57	1.73	40.83	21.76	2.21	-4.53	36.68	2.48	-2.64	20.10	1.22	-6.63
JPO-14	147	-0.75	125.49**	175	0.71	8.39	110.71	2.83	644.16**	16.85	-0.09	2.98	23.34	0.65	2.13	18.69	-2.23	7.76
JPO-17	148	2.64*	-5.32	179	1.85	-2.44	92.13	1.71	149.17*	20.95	1.77	-4.06	33.91	0.50	-3.12	19.02	0.33	-6.69
JPO-18	156	0.73	-3.52	179	1.32	63.16	97.32	1.57	172.34*	22.70	1.1	-4.83	27.07	0.54	-1.61	21.90	-0.61**	-6.71
JPO-19	154	1.29	62.02**	181	1.73*	-7.06	93.49	1.00	310.24**	21.61	1.98	-2.91	21.53	0.54	-1.57	20.24	3.48	-6.30
JPO-20	136	0.31	-5.18	171	0.94	-3.26	96.04	1.94	136.46	24.91	2.63	9.07	33.47	0.94	-9.30	23.55	3.14	-1.86
JPO-21	147	2.49	6.61	179	1.22	13.00	110.75	3.79	-28.69	22.78	1.25	9	38.79	-0.32	-7.75	24.69	-0.64**	-6.71
JPO-22	146	1.15*	-5.38	176	0.62	-4.07	91.96	1.30	-7.51	20.80	1.91	-4.92	33.06	0.37	-9.54	18.98	2.26	-6.51
JPO-24	135	0.42	-2.73	170	0.74**	-7.55	116.08	-0.22	239.33*	24.11	0.89	5.35	37.73	4.52	22.24	27.75	0.83	-6.66
JPO-25	139	3.39*	-4.23	167	0.33	-6.56	76.50	0.00	13.46	27.41	-1.16	26.40*	40.05	3.74	11.69	20.52	-1.07	-2.68
JPO-28	149	0.84	-3.15	178	1.21	-4.49	96.54	-0.88	-45.78	23.34	1.51	7.11	23.41	-0.88	-5.44	22.48	3.10	-6.37
JPO-29	153	3.14	5.46	182	2.16	7.90	116.69	0.03	108.58	15.72	-1.78	112.46**	24.63	0.50	-3.18	18.60	0.70	232.51**
JPO-3	136	2.13	5.29	171	1.16	2.04	96.20	0.11	-13.08	23.96	1.24	0.29	37.47	5.75	-9.19	22.94	1.50*	-6.69
JPO-30	152	1.78	28.37*	178	1.02	0.79	112.08	3.28	360.71**	21.73	1.52*	-5.38	24.57	0.15	-10.15	23.96	-1.22*	-6.69
JPO-31	150	-0.32	21.16*	179	1.15*	-6.87	105.13	1.46	-38.05	17.53	-0.6	1.72	25.01	-3.24	-3.01	18.55	-0.99	15.10
JPO-35	141	0.90	119.21**	175	1.14	6.66	102.33	1.37	215.73*	22.40	2.04	-0.63	29.92	-1.67	-5.41	22.52	1.19	-6.63
JPO-36	153	0.90	53.95**	181	1.10	12.78	114.53	4.01	53.00	18.29	1.26	11.8	25.21	-0.04	-10.77	20.61	0.52	45.65**
JPO-38	147	-0.18**	-5.44	174	0.52	-7.37	102.55	-2.12	-2.25	26.58	0.01	-0.07	37.94	0.60	0.37	27.18	2.39	-6.50
JPO-4	147	2.10	0.49	177	1.09	-5.10	92.57	4.01	-38.98	23.01	-0.38	1.03	33.01	-0.45	-10.77	21.56	-1.37	75.11**
JPO-40	147	0.24	-5.40	173	1.06*	-7.22	112.50	-1.39	74.12	22.93	1.91	2.27	24.24	-2.41	-9.26	26.03	5.62	-5.75
JPO-41	153	1.13	-4.78	179	1.54	26.14	104.66	3.53*	-50.41	21.08	2.01	-2.87	26.11	0.63	1.40	21.40	0.62	-6.68
JPO-44	140	2.24	255.63**	176	0.61	-2.42	90.79	-1.36	-49.54	24.75	1.22	11.14	35.20	-0.87	12.59	22.54	3.16	-6.37

Genotypes	Days to 50% flowering			Days to 75% maturity			Biological yield per plant(g)			Harvest index(%)			1000-seed weight (g)			Seed yield per plant (g)		
	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di	Mean	bi	S^2 di
JPO-45	151	1.51	85.19**	178	0.29	-6.79	112.54	0.46	121.60	24.06	0.85	-0.91	26.27	0.42	-5.29	26.91	0.32	-6.69
JPO-46	156	2.08	22.57*	182	1.70	20.59	103.00	4.48	543.28**	21.75	1.27	37.03**	29.85	0.31	-7.83	21.45	0.48	-6.68
JPO-5	142	1.44	-3.25	175	1.59	3.16	94.91	1.19	14.25	20.23	2.58	23.20*	26.81	1.31	-9.72	19.04	0.84	39.26**
JPO-50	154	1.92	13.16	181	0.97	-5.18	115.19	1.54	100.67	24.25	1.09	-0.8	32.21	0.45	-4.49	27.72	1.70	-6.58
JPO-55	155	0.59	2.91	177	1.28	1.88	97.88	1.25	-42.77	21.79	-0.11	-3.03	32.36	-0.20	-9.61	21.44	-1.49*	-6.68
JPO-73	152	1.70	17.46*	178	0.78	18.55	95.77	2.95	36.67	25.15	1.34	13.58	31.66	1.44	-6.81	23.53	0.13	-6.70
JPO-8	138	1.93	49.92**	170	0.60	8.58	73.74	0.18	-2.85	23.53	-0.75*	-5.38	37.57	-1.17	31.50*	17.41	-1.47*	-6.68
K-353	137	-0.09	-2.11	172	0.80	0.12	82.96	0.72	3.04	26.77	-0.42	19.51*	42.84	6.58	-4.54	22.05	-0.87	-5.41
KRR-AK-06	135	0.01	35.71**	171	1.01**	-7.55	108.96	-0.79	14.91	25.17	0.04	2.77	39.02	1.74	1.74	27.39	0.39	-6.62
KRR-AK-15	151	1.35	9.79	179	1.50*	-7.04	115.33	1.75	8.92	24.45	4.4	-2.66	32.01	-1.50	-7.98	27.97	7.17	-5.19
KRR-AK-26	156	1.24	5.12	181	1.38*	-6.95	104.83	2.37	119.12	23.25	1.09	-5.32	24.43	0.02	-10.82	24.12	-1.06*	-6.70
KRR-AK-36	148	1.90	7.59	177	1.08	7.16	107.96	-2.11	687.03**	21.94	2.86	8.42	24.08	0.21	-9.43	24.54	8.82	-4.48
KRR-AK-42	137	-0.10	22.53*	170	0.88	-0.68	93.25	-2.19	128.14	25.88	0.23	59.96**	38.06	3.07	-4.40	24.37	-1.56	129.76**
KUE	154	0.91	-3.78	178	1.08*	-7.31	104.32	1.94	180.81*	22.18	1.48	-4.89	33.94	1.00	-9.48	22.83	-0.09	-6.70
No. 77	139	0.49	-5.07	170	0.80	-1.60	98.29	-1.55	-14.65	25.50	0.28	-5.21	29.07	1.17	-10.34	25.12	1.97	-3.83
Oat-102	136	0.44	-4.56	173	0.67	-7.28	116.93	1.99	-48.41	24.44	0.58	-1.32	40.42	6.15	4.73	28.39	-0.51**	-6.71
Oat-17	135	0.60	-2.16	175	0.95	-1.44	115.71	0.77	-23.00	25.36	1.21	-4.28	33.77	0.17	-10.39	29.36	1.30	-6.62
Oat-79	138	0.36	-1.55	174	0.39	20.15	109.99	0.66	74.07	22.32	1.26	-2.38	35.85	4.35	-1.19	24.49	1.02	-6.65
Oat-80	144	2.02	-0.82	177	1.24	3.58	73.88	0.01	62.21	22.54	3.94	27.74*	37.28	-1.45	18.51	16.27	4.21	-6.14
Oat-8655	137	-1.63	58.49**	173	0.97	91.53	111.25	-0.24	383.70**	25.59	0.91	13.06	34.61	0.18	-10.53	28.15	0.52	-6.68
Oat-902	152	0.51**	-5.44	177	1.16	2.04	101.04	3.34	245.21*	19.82	1.16	-4.64	35.71	3.19	91.33**	19.75	-1.63*	-6.67
OG-77	142	-0.53	13.42	168	0.48	46.96	96.58	-0.82	178.48*	23.58	0.93*	-5.39	34.14	1.01	-10.30	23.01	3.36	-6.33
OL-125	144	0.31	-3.87	173	0.91	-6.79	94.46	-1.36	340.14**	27.28	-0.95	-0.29	29.28	1.31	27.82	25.29	1.64	-6.59
OL-161	143	1.24*	-5.36	177	0.91	-6.79	102.58	3.37	-2.98	22.43	0.91	12.18	32.57	1.02	-3.55	22.78	-0.72**	-6.71
OL-822	142	1.26	4.57	169	0.81	-3.39	113.08	1.67	439.48**	20.66	1.44	0.43	33.40	5.37	-6.00	23.17	2.96	-6.40
OL-9	138	1.00	-3.91	172	1.20	2.82	107.03	4.08	1269.47**	27.26	2.81	-4.54	29.29	0.75	76.38**	27.89	-2.50*	-6.62
OS-10	147	0.54	26.26*	172	0.80	25.88	103.71	0.27	-24.62	25.24	1.07	50.47**	32.77	-0.21	-9.44	26.44	3.67	42.29**
OS-121	140	2.48	11.98	176	1.59	-3.80	109.38	-0.11	110.48	23.81	0.66	-4.96	39.14	4.03	-1.22	26.10	2.26	-6.51
OS-9	150	3.72*	-4.60	181	1.96	28.77	76.42	2.15	83.13	19.42	1.31*	-5.35	24.57	-0.20	-9.57	14.63	-0.60**	-6.71
OS-92	136	-0.22	-3.74	176	1.10	-2.83	93.71	0.42	-26.48	25.45	0.76	-5	33.92	1.09	30.87	23.82	1.25	-6.63
PO-1	134	0.48	-5.24	171	1.00	-2.65	118.17	3.29*	-49.51	23.57	1.48	0.47	43.15	6.72	2.31	27.39	0.05	-6.70
S8-217	134	0.71	-4.98	173	1.13	-3.95	98.54	1.75	224.97*	19.42	1.69	-1.66	37.53	2.77	6.84	19.01	2.51	-6.48
Sabzaar	136	0.04	-5.31	173	1.09	-4.40	104.32	3.98	-0.37	23.98	3.3	2.81	39.62	-0.37	0.46	24.17	2.30	-6.51
SK-150	151	2.43	13.88	179	1.37*	-7.41	84.45	-2.78	740.93**	27.55	-2.89	18.48*	23.82	0.17	-9.96	22.04	0.89	-6.66
SK-199	157	0.27**	-5.43	177	0.91	11.24	94.28	2.10	-39.51	22.29	1.01	-0.39	29.37	-0.29	-8.29	20.77	0.14	-6.70
SKO-28	149	2.30*	-5.18	179	1.54*	-7.20	108.38	2.96	-35.85	16.75	-1.06	-3.32	33.89	0.56	-1.08	18.40	-2.38	26.29*
SNTM-90	135	0.18**	-5.44	168	0.55**	-7.53	101.18	1.21	861.39**	23.70	0.03	30.52*	36.88	1.26	-10.14	23.37	1.77	-6.58

Genotypes	Days to 50% flowering			Days to 75% maturity			Biological yield per plant(g)			Harvest index(%)			1000-seed weight (g)			Seed yield per plant (g)		
	Mean	**bi**	**S^2 di**	**Mean**	**bi**	**S^2 di**	**Mean**	**bi**	**S^2 di**	**Mean**	**bi**	**S^2 di**	**Mean**	**bi**	**S^2 di**	**Mean**	**bi**	**S^2 di**
TRS-106	144	1.89	22.49*	169	0.65	-2.97	85.00	-0.77	-44.72	27.75	-0.14	21.79*	37.77	1.38	-7.64	23.44	1.57	0.64
UPO-102	139	0.63	9.76	173	1.11	-2.54	82.38	0.52	-31.80	25.25	1.52	13.96	30.62	3.24	-9.04	20.73	0.01	14.02
UPO-102-1649	135	1.15*	-5.38	171	1.14	-2.27	110.50	3.84	-42.37	23.50	0.32	16.90*	40.40	-0.09	-10.57	25.58	-2.36*	-6.62
UPO-119	131	-0.77	2.35	168	0.93	-4.78	100.88	1.62	-4.24	24.45	0.82	-5.09	41.56	3.40	-4.20	24.52	-0.61**	-6.71
UPO-130	144	1.86	4.35	174	0.68	-6.66	85.46	1.63	-49.36	26.81	2.45*	-5.19	35.89	2.19	-0.30	22.18	1.72	-6.58
UPO-30	143	1.84*	-5.38	175	1.08	30.75	108.29	0.43	474.07**	22.18	1.6	-3.52	31.24	-4.88	-5.82	24.07	4.17	-6.15
Kent (C)	149	0.38	-3.83	178	1.10	-2.83	104.33	0.49	-32.97	22.25	0.38	-5.37	33.48	1.02	-9.94	23.25	0.69	-6.45
OS-6 (C)	146	2.29	11.17	182	1.53	11.22	100.71	3.46**	-50.69	16.90	1.58	-1.96	28.17	0.87	-4.19	16.79	0.32	-6.69
PLP-1 (C)	144	1.22	-4.86	175	0.66	-5.00	106.16	1.10	2.66	20.04	1.71	5.37	30.41	-0.09	-1.55	21.10	1.83	5.31
RO-19 (C)	143	-0.62	-4.91	175	0.87	-6.99	89.83	4.04	188.81*	24.66	0.15	53.83**	31.16	0.87	-10.68	21.39	-1.76	-6.23
UPO-212 (C)	140	-0.49	-5.07	179	0.51	-3.96	72.00	1.38	-5.91	30.61	-0.26	19.94*	30.07	0.44	15.15	21.39	-0.98*	-6.70
Grand mean	144	1.00	-	175	1.00	-	100.90	1.00	-	23.19	1	-	32.94	1.00	-	23.06	1.00	-
S.E (m) ±	3.00	1.00	-	2.50	0.40	-	10.60	2.00	-	2.50	1.2	-	2.31	2.19	-	1.94	1.47	-

, Significance at 5 and 1% of deviation regression from zero in case of S2di (mean square deviation) and of regression coefficient from unity in case of bi (regression coefficient)*

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