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Identification of promising and stable genotypes of oat (*Avena sativa* L.) for green fodder yield under varied climatic conditions of north-western Himalayas

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Abstract
The present investigation was undertaken to determine the stability of oat genotypes for green fodder yield under varied environmental conditions prevalent in north-western Himalayas. A total of 121 genotypes including five checks were evaluated during three cropping seasons (*Rabi* 2014-15 to 2016-17). The stability was estimated using Eberhart and Russell model for six traits *viz.,* plant height, leaves per plant, tillers per plant, flag leaf area, leaf: stem ratio and green fodder yield per plant. The pooled analysis of variance showed differential behavior of genotypes over the environments. The most stable genotypes identified for plant height, leaves per plant, tillers per plant, flag leaf area and leaf: stem ratio were JPO-35, IG-03-254, JPO-31, JPO-44 and IG-03-250, respectively. However, the promising and stable genotypes for green fodder yield identified were SKO-28, JHO-822, Oats-902 and IG-03-214. Thus, the genotypes found stable and well adapted to all the types of environments could be exploited as elite gene pool in future breeding programme, where aim is to develop high yielding and stable genotypes over environments or could be further tested in multilocation trials to be released as a cultivar.

Keywords: Green fodder yield, G×E interactions, Oat genotypes, Stability

Introduction

Oat is a cereal crop of Mediterranean origin (Stevens *et al.,* 2004). Preference to oat cultivation as a grain crop in central and western Europe and as fodder in Asia minor is available since Christian era (Vavilov, 1926). Oat is an economically important crop and ranks sixth in world cereal production after wheat, maize, rice, barley and sorghum. In India it is used as green fodder, straw, hay or silage; occupying 100 thousand ha area with forage productivity of 35–50 tons/ha (Anonymous, 2014). Green fodder contains about 10-12 percent protein and 25-30 percent dry matter (Mishra and Verma, 1985).

In India, oat is cultivated in Himalayan states like Kashmir, Himachal Pradesh and Uttarakhand. Oats in these regions have a wider adaptability because of its excellent growing habitat, quick re-growth, better nutritional value with drought and cold tolerance ability. Himalayan region mainly consists of low, medium and high hills but the cultivation of fodder is restricted mainly to the lower hills. Beyond this zone, the cultivation of fodder is not practical because maximum area is under high value cash crops (Sharma *et al.* 2018). Also the climatic conditions change very quickly in the Himalayan region due to change in the altitude. And the average fodder yield of the crop varies with varying environmental conditions. Therefore, the development of varieties well adapted to varied environmental conditions, is the ultimate goal of plant breeders in crop improvement program. The adaptability of a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is planted. The genotype x environment (G×E) interactions could be attributed to predictable effects, that may be due to macro-environmental conditions and non-predictable effects, mainly caused by climatic and micro-environmental conditions as reported by Allard and Bradshaw (1964). A variety or genotype is considered to be more adaptive or stable if it has a high mean yield but a low degree of fluctuation in yielding ability when grown in diverse environments.

Many models have been developed to measure the stability of various parameters. Among those the most widely used model (Eberhart and Russell, 1966) has been followed to interpret the stability statistics in various crops. He suggested that the regression coefficient (b_i) and deviation from regression (S^2_{di}) may be considered as two parameters for measuring the varietal phenotypic stability. The variety with (b_i) value did not significantly differ from unity (b_i=1) and (S^2_{di}) did not significantly differ from zero could be described as a stable variety. Thus the present investigation was undertaken to identify the promising and stable genotypes of oat under varied environmental conditions of north-western Himalayas for green fodder yield.

Materials and Methods

Experimental site: The experiment was conducted for three consecutive years from *Rabi* 2014-15 to 2016-17 at Experimental Farm of the Fodder Section, CSK HPKV, Palampur which is situated at 32°6' N latitude, 76°3' E longitude at an elevation of 1290.8 m (a.m.s.l.). Agro-climatically the location represents the mid-hill zone of Himachal Pradesh (Zone-II) and is characterized by humid sub-temperate climate with high rainfall (2500 mm). The soil is acidic in nature with pH ranging from 5.0 to 5.6 and soil texture is silty clay loam.

Plant material and statistical analysis: The experimental material comprised of 121 oat germplasm lines including five checks *viz.,* Palampur-1, OS-6, Kent, RO-19 and UPO-212 were evaluated using simple lattice design. Each genotype was grown in two rows of one-meter length with 25 x 5 cm spacing. The plot size was kept 1.0 x 0.5 m. The data was recorded on five randomly selected competitive plants in each replication on six quantitative traits *viz.,* plant height (cm), leaves per plant, tillers per plant, flag leaf area (cm^2), leaf: stem ratio and green fodder yield per plant (g). Data on these traits was subjected to analysis of variance to find significant differences among genotypes for the recorded data. After obtaining the significant differences, data were subjected to stability analysis according to Eberhart and Russel (1966).

Results and Discussion

Significance of mean squares: The pooled analysis of variance (Table 1) showed significant differences among the genotypes and environments for all the traits studied, which revealed that there was considerable variation present both among the genotypes and environments. Similar findings for genotypic and environmental variation under different environments were also observed by Sah *et al*. (2016). The mean sum of squares for G × E interaction were significant for plant height, flag leaf area, leaf: stem ratio and green fodder yield per plant and for E + (G × E) for all the traits, indicating differential response of genotypes to different environments. The magnitude of genotypes and environmental variances was observed to be higher than of G × E interaction for all the traits. Further the higher magnitude of mean squares due to environments (linear) as compared to G × E (linear) revealed that the considerable differences in the environments accounted for major part of total variation for most of the traits studied which was mainly due to variation in weather and temperature during different cropping seasons.

Variance due to G× E (linear) was significant for the traits *viz.,* plant height, flag leaf area, leaf: stem ratio and green fodder yield per plant which revealed that the major component for differences in stability was due to linear regression and the performance can be predicted with some reliance under different environments for these traits. Similarly, the significant mean squares due to pooled deviation or non-linear component of G ×E interaction suggested that the deviation from linear regression also contributed substantially towards the difference in stability of genotypes for leaves per plant, tillers per plant and green fodder yield per plant.

Thus, both linear (predictable) and non-linear (unpredictable) components significantly contributed to genotype x environment interactions observed for the traits but with the predominance of the former component suggesting that the performance of genotype across

Table 1. Joint regression analysis of variance for green fodder yield and related traits over environments

Source of variation	d.f.	Plant height (cm)	Leaves per plant	Tillers per plant	Flag leaf area (cm^2)	Leaf: stem ratio	Green fodder yield per plant (g)
Genotypes	120	508.55*	90.21*	5.32*	296.63*	0.01*	573.80*
Environments	2	4574.03*	5245.90*	250.25*	336.92*	0.05*	2387.46*
G ×E	240	74.08*	38.61	2.61	5.81*	0.003*	268.29*
Environments + G ×E	242	111.27*	81.64*	4.66*	8.55*	0.003*	285.80*
Environment (linear)	1	9148.06*	10491.80*	500.51*	673.84*	0.11*	4774.91*
G ×E (linear)	120	126.50*	36.5	2.33	9.74*	0.01*	317.24*
Pooled Deviation (non-linear)	121	21.49	40.37*	2.87*	1.87	0.0004	217.52*
Pooled error	360	37.06	17.05	0.65	6.89	0.001	60.26

*Significant at P<0.05;

Table 2. Estimates of stability parameters for plant height, leaves per plant and tillers per plant in oat

Genotypes	Plant Height (cm)		Leaves per plant		Tillers per plant	
	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})
99-1	2.27	15.42	1.08	-15.50	1.54	2.44*
ADG-214	-0.42	-34.08	1.86	-9.95	1.96	-0.55
ADG-96	0.37	-27.11	0.91	48.28	0.90	-0.53
AVE-3018	1.58*	-38.81	0.70	27.53	0.28	-0.60
Chorripatli	0.98	-36.23	0.89*	-17.08	1.21	-0.48
EC-523890	-2.86	270.31**	2.91	90.18*	2.79	0.21
EC-528865	0.90	-33.30	0.57	186.57**	-0.09	6.41**
EC-528883	4.52*	-36.97	-0.32	25.08	-1.04	0.18
EC-528889	2.91*	-37.39	0.31	13.34	0.27	0.32
EC-528890	2.36*	-38.64	2.82	66.83*	3.15	1.65
EC-528894	2.44	-35.65	1.29	57.58*	1.05	17.67**
EC-528895	-0.57	-29.68	1.04	14.77	0.48	-0.65
EC-528896	-1.51*	-38.77	0.60	-4.26	0.99	3.19*
EC-528897	2.40	-36.96	1.92	358.29*	1.38	19.76**
EC-528898	0.67	-36.65	0.42	-14.82	-0.24	-0.48
EC-528903	0.41	-38.31	1.66	-14.59	1.48	0.51
EC-528905	0.11	-30.29	0.48	5.34	0.00	10.98**
EC-528913	1.48	-29.39	1.25	5.46	0.48	-0.55
EC-558905	2.25	26.18	1.54	-7.74	1.41	1.44
EC-605831	1.07	-33.66	0.48	16.52	0.39	3.37*
EC-605832	2.90**	-38.90	1.01	214.19**	1.38	19.76**
EC-605834	0.41	-34.81	0.95	-14.49	0.82*	-0.68
EC-605837	-0.20	-34.24	1.32	13.37	1.35	0.06
EC-605838	1.39**	-38.92	2.12	-5.44	2.17	-0.03
EC-605839	1.48	-37.65	1.67*	-16.78	2.09	-0.33
Fragrati	2.22	-24.59	-0.03	-1.35	0.08	-0.64
H-B-8	0.93	-3.66	0.49	97.23*	0.38	1.28
HFO-102	1.96	64.62	0.85	-7.94	1.12	-0.33
HFO-114	1.07	-0.48	1.04	12.89	1.03*	-0.66
HFO-163	0.78**	-38.94	0.31	-10.36	0.25	-0.67
HFO-52	0.49	-14.57	0.69	43.15	0.76	0.71
HJ-8	0.27**	-38.91	0.39	-13.96	0.03	-0.64
IG-03-203	-0.30	-36.46	0.37	54.87*	0.16	6.91**
IG-03-205	0.39	83.96	1.06	-16.12	1.94	-0.39
IG-03-208	-0.72	48.40	1.08	2.40	1.20	-0.03
IG-03-211	-0.82	36.81	0.10	21.31	-0.15	-0.33
IG-03-213	2.09*	-37.85	0.97	-16.28	1.47	0.47
IG-03-214	-1.33	-35.13	0.66	-13.44	0.34	1.55
IG-03-216	-0.80	-36.93	1.27	192.12**	1.07	7.79**
IG-03-246	1.24**	-38.94	2.01	54.85*	2.42	3.23*
IG-03-247	0.25	45.83	0.44*	-17.20	0.95	-0.55
IG-03-250	0.39	-34.01	1.33	-10.46	1.36*	-0.66
IG-03-251	0.86	-32.57	0.75*	-16.95	0.94	-0.56
IG-03-254	2.37	-34.45	0.70	46.31	1.66	0.00
IG-03-48	4.07*	-38.58	1.00	213.03**	2.50	11.17**
IGO-14	1.42*	-38.58	1.29	33.28	0.94	-0.56
JH0-862	0.89	91.28	2.04*	-16.08	1.64	0.73

Stability analysis of oat genotypes

Genotypes	Plant Height (cm)		Leaves per plant		Tillers per plant	
	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})
JHO-813	-0.46	-36.23	1.90	75.99*	2.21	3.64*
JHO-822	0.63	139.64*	0.66	134.64**	1.35	22.51**
JHO-99-2	0.86	-37.51	1.08	-14.49	1.10	-0.58
JPO-10	1.70*	-38.54	1.04	16.83	0.40	-0.66
JPO-13	0.92*	-38.87	1.24	-14.23	1.42	6.66**
JPO-14	-0.14	-36.09	1.26	-15.94	0.75	2.91*
JPO-17	1.33*	-38.82	0.06	18.13	-0.50	0.92
JPO-18	-0.52	-27.62	1.48*	-16.22	1.32*	-0.66
JPO-19	4.25*	-33.58	0.78	-11.15	1.01	0.45
JPO-20	1.17	10.28	1.19	-5.03	1.79	-0.45
JPO-21	-0.12	-36.14	1.42	-4.27	1.71	-0.02
JPO-22	-1.31	-17.76	1.47	71.37*	1.64	11.73**
JPO-24	1.21	-34.09	0.68	54.61*	1.12	11.36**
JPO-25	4.05	-26.71	0.98	30.99	1.15	0.01
JPO-28	0.35	-38.51	0.68	17.22	0.68	1.60
JPO-29	1.44	-37.64	0.79	-15.81	1.12*	-0.68
JPO-3	0.95	20.77	1.51	37.33	1.75	3.68*
JPO-30	-0.34	-38.78	0.11	47.00	-0.28	0.00
JPO-31	0.35	-24.18	0.32	4.20	0.98	0.89
JPO-35	0.78	-29.80	1.11	39.40	1.77	-0.50
JPO-36	1.27	-37.73	0.51	11.39	0.53	8.55**
JPO-38	2.02	-29.44	1.05	-11.90	0.46	-0.40
JPO-4	1.03	-20.65	1.38	102.91**	1.35	8.89**
JPO-40	-0.30	-27.43	0.31	19.98	0.32	1.74
JPO-41	1.15	-27.99	0.67	-15.85	0.84	-0.58
JPO-44	1.89*	-37.47	1.66	-3.92	0.85	3.41*
JPO-45	2.47**	-38.93	1.83**	-17.21	1.09	1.25
JPO-46	1.77	-36.76	-0.21	-12.06	-0.84	0.04
JPO-5	-0.09	-30.21	0.64*	-17.21	1.46*	-0.65
JPO-50	0.69	-34.11	1.38	94.98*	0.83	5.03**
JPO-55	-2.69	-24.88	2.00	28.01	2.03	3.83*
JPO-73	0.24	-4.52	1.34	-16.05	0.88	-0.12
JPO-8	-1.40*	-38.24	1.25	4.63	1.58	0.59
K-353	0.40	-31.39	0.68	24.21	0.43	1.33
KRR-AK-06	0.93**	-38.93	2.02*	-16.69	1.42	0.50
KRR-AK-15	-0.05	-37.32	0.57	-16.93	1.15	-0.60
KRR-AK-26	0.97**	-38.94	0.21	-16.86	0.18	0.01
KRR-AK-36	-0.73	-33.81	1.82	-12.85	1.19	5.25**
KRR-AK-42	2.58*	-35.95	1.31	-10.84	1.24	0.32
KUE	0.15	-38.54	1.13	49.78*	1.42	0.50
No. 77	1.13	23.99	0.19	-2.08	0.75	0.28
Oats-102	1.96	-24.29	2.08	45.79	1.43	-0.40
Oats-17	1.65	-9.16	2.06	-2.80	1.52	2.64*
Oats-79	0.72	-35.33	1.92	-4.27	2.05	-0.22
Oats-80	1.92*	-38.07	1.07	-16.05	1.61*	-0.62
Oats-8655	0.39	-33.19	1.05	-13.39	1.30	1.23
Oats-902	1.54	-35.91	0.17	-8.84	0.42	0.96
OG-77	0.61	-38.71	1.60	85.29*	1.16	1.71

Genotypes	Plant Height (cm)		Leaves per plant		Tillers per plant	
	(b_i)	($S^2{}_{di}$)	(b_i)	($S^2{}_{di}$)	(b_i)	($S^2{}_{di}$)
OL-125	2.51	-22.98	1.58	4.21	1.37	0.83
OL-161	2.68	-28.62	0.62	3.77	0.82	-0.45
OL-822	3.11*	-38.78	0.89	-15.95	1.27	-0.26
OL-9	0.20	-37.29	1.44	34.21	1.74	4.43**
OS-10	0.66	-38.30	-0.42	-12.76	0.10	-0.68
OS-121	1.55	-37.34	0.67	41.51	0.69	6.17**
OS-9	0.31**	-38.92	0.64	27.75	0.10	-0.43
OS-92	1.36	-35.05	1.49	-15.37	1.53	-0.36
PO-1	1.80	141.58*	1.00**	-17.24	0.73	-0.48
S8-217	1.57	93.62	0.85	143.45**	1.13	6.91**
Sabzar	0.66	-37.62	1.35	-9.79	1.15	-0.60
SK-150	-1.60	-19.24	-0.13	83.28*	-1.06	2.67*
SK-199	1.16	-36.72	-0.45	-16.39	-0.35	-0.66
SKO-28	2.82	-34.68	1.35	7.22	1.26	-0.50
SNTM-90	2.20	-33.36	1.79	71.08*	2.03	1.82
TRS-106	0.76	-26.54	0.56	-16.05	1.38**	-0.68
UPO-102	1.66*	-37.71	-0.25	18.08	-0.34	0.23
UPO-102-1649	2.88	16.19	1.61	44.58	0.90	3.12*
UPO-119	1.48	-36.72	1.04	84.48*	1.16	2.81*
UPO-130	2.66*	-37.42	1.96**	-17.24	2.05	2.07*
UPO-30	1.37	-15.73	1.03	-8.07	0.31	-0.68
Kent (C)	0.86	-18.08	0.42	-10.20	1.02	0.53
OS-6 (C)	0.49	-0.11	0.64	-12.23	1.04	-0.53
PLP-1 (C)	2.34	77.47	0.68	-14.60	0.59	5.84**
RO-19 (C)	1.01	1.37	-0.11	62.90*	0.28	12.99**
UPO-212 (C)	0.15	-18.60	1.06	-16.62	0.72	2.25*
Grand mean	1.00	-	1.00	-	1.00	-
S.E (m) ±	0.50	-	0.68	-	0.83	-

*,** Significance at 5 and 1% of deviation regression from zero in case of **$S^2{}_{di}$ (mean square deviation)** and of regression coefficient from unity in case of **b_i (regression coefficient)**.

environments could be predicted with greater precision. Similar findings were reported by Mehraj *et al.* (2017), Ahmad *et al.* (2016), Nehvi *et al.* (2007) and Altaf *et al.* (2003). The non-significance of linear mean square against pooled deviation indicated that the reliable prediction of G× E interaction could not be made for leaves per plant and tiller per plant. However, even for unpredictable traits, prediction could be made based on stability parameters for individual traits (Singh *et al.,* 1991).

Stability analysis: The stability parameters (b_i&$S^2{}_{di}$) for all the traits were rerecorded (Table 2-3). According to regression model of stability proposed by Eberhart and Russell (1966), b_i is considered as a parameter of response and $S^2{}_{di}$ indicates instability due to the deviation from zero. 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 mean values ranged from 64.67-139.58 cm with average value of 113.30 cm for plant height. Considering the genotypes showing above average performance for all the traits, genotypes JPO-35, H-B-8, KRR-AK-06, Chorripatli, EC-528865, Kent, IG-03-251, JHO-862 and JHO-99-2 with mean values of 133.67, 125.72, 124.15, 124.05, 124.00, 120.02, 119.73, 118.88 and 115.27 cm, respectively were found stable over all the environments for plant height and based on their significant regression coefficients (b_i>1), the most responsive genotypes performed better under favourable environments were EC-528883, JPO-19 and IG-03-48.

The mean values ranged from 22.29-53.75 with average value of 37.63 for leaves per plant. For this trait, six genotypes IG-03-254, JPO-29, JPO-19, IG-03-213, JPO-41 and OS-121 with high mean performance of 45.21, 43.89, 43.00, 40.63, 40.08 and 39.00 leaves per plant, respectively, were found stable and while most

Table 3. Estimates of stability parameters for flag leaf area, leaf stem ratio and green fodder yield per plant in oat

Genotypes	Flag leaf area (cm^2)		Leaf: stem ratio		Green fodder yield/plant (g)	
	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})
99-1	1.81**	-6.98	-1.55	-0.001	-0.87	121.13
ADG-214	-1.18	-6.58	2.42**	-0.001	2.89	-57.19
ADG-96	0.61	-6.90	1.56**	-0.001	-2.12	422.92**
AVE-3018	0.61	-6.90	4.94	0.000	-4.17	-41.78
Chorripatli	1.81**	-6.98	2.16	-0.001	0.53	-58.35
EC-523890	2.56*	-6.97	3.32	-0.001	6.03*	-60.13
EC-528865	1.51*	-6.97	3.41	-0.001	-1.12	209.56*
EC-528883	0.01	-6.82	1.10**	-0.001	-3.71	311.19*
EC-528889	2.10*	-6.99	1.56**	-0.001	-0.59	727.09**
EC-528890	0.91	-6.93	-2.94	0.000	2.24	76.52
EC-528894	1.35*	-6.98	0.53**	-0.001	2.67	-26.91
EC-528895	3.30*	-6.94	-1.55	-0.001	1.72	-48.72
EC-528896	2.55*	-6.91	-2.11	0.000	1.77	495.50**
EC-528897	1.51*	-6.97	0.30**	-0.001	-4.35	1978.89**
EC-528898	3.44*	-6.78	1.33**	-0.001	-0.49	371.50**
EC-528903	0.01	-6.82	1.93**	-0.001	4.94	213.78*
EC-528905	0.17	-6.65	2.16	-0.001	0.34	-55.55
EC-528913	0.75*	-6.98	1.36**	-0.001	1.55	-32.27
EC-558905	0.61	-6.90	1.79	-0.001	0.98	96.16
EC-605831	1.96*	-6.93	2.72	-0.001	-2.11	61.13
EC-605832	2.70*	-6.98	3.08	-0.001	-2.85*	-59.05
EC-605834	0.61	-6.90	-0.95	-0.001	3.44	-54.25
EC-605837	0.01	-6.82	3.32	-0.001	3.01**	-60.60
EC-605838	0.45	-6.97	3.55	-0.001	2.36	841.81**
EC-605839	0.61	-6.90	0.77**	-0.001	-0.07	296.51*
Fragrati	1.05**	-6.99	-3.50	0.000	-1.06	-32.99
H-B-8	1.21*	-6.96	0.07	-0.001	3.68	286.44*
HFO-102	-0.44	-6.90	3.32	-0.001	-2.70	254.00*
HFO-114	2.86**	-6.98	3.18	-0.001	5.12	-48.32
HFO-163	0.31	-6.86	0.07	-0.001	-3.74	312.92*
HFO-52	0.01	-6.82	1.23**	-0.001	7.97	65.51
HJ-8	0.91	-6.93	-2.25	-0.001	1.01	-60.09
IG-03-203	-1.18	-6.58	5.04	0.000	3.69	-50.28
IG-03-205	1.35*	-6.98	2.62	-0.001	6.16	-45.58
IG-03-208	2.86**	-6.98	-0.06**	-0.001	7.89*	-56.30
IG-03-211	0.31	-6.86	2.75	-0.001	-1.74	14.60
IG-03-213	0.45	-6.97	-2.71	0.000	2.84	-17.49
IG-03-214	-0.58	-6.72	-3.64	0.000	1.29	-44.07
IG-03-216	-1.04	-6.82	4.11	-0.001	2.60	1231.70**
IG-03-246	1.81**	-6.98	1.60**	-0.001	4.28	1721.79**
IG-03-247	0.91	-6.93	-0.39	-0.001	-2.35	83.49
IG-03-250	1.07	-6.82	1.00**	-0.001	0.04	-50.50
IG-03-251	-1.64	-6.72	-0.03	-0.001	-2.96	28.33
IG-03-254	-0.14	-6.93	4.34	0.000	1.51*	-60.48
IG-03-48	-1.02	-6.33	4.38	-0.001	-1.04	215.66*
IGO-14	1.36	-6.86	-0.29	-0.001	3.56	151.27
JH0-862	1.35*	-6.98	4.24	-0.001	3.68	306.85*

Genotypes	Flag leaf area (cm^2)		Leaf: stem ratio		Green fodder yield/plant (g)	
	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})
JHO-813	0.77	-6.77	0.20	-0.001	7.55	334.94*
JHO-822	-0.88	-6.65	1.46**	-0.001	1.46	-56.47
JHO-99-2	-1.48	-6.51	2.29	-0.001	0.47	22.09
JPO-10	1.36	-6.86	-0.76	-0.001	-0.29	175.76*
JPO-13	3.46**	-6.98	-2.58	0.000	2.15	64.01
JPO-14	1.35*	-6.98	-0.95	-0.001	2.14	278.62*
JPO-17	0.61	-6.90	1.23**	-0.001	2.02	42.18
JPO-18	2.40**	-6.98	2.75	-0.001	1.78	26.67
JPO-19	-2.08	-6.34	-2.25	-0.001	-1.88	312.01*
JPO-20	1.07	-6.82	1.79	-0.001	1.80	17.45
JPO-21	2.10**	-6.99	-3.50	0.000	2.81	-49.83
JPO-22	0.31	-6.86	1.10**	-0.001	-1.03	-18.68
JPO-24	2.10**	-6.99	0.53**	-0.001	0.57	283.07*
JPO-25	1.51*	-6.97	0.53**	-0.001	-2.19	47.65
JPO-28	4.04*	-6.66	0.07	-0.001	0.54	-52.66
JPO-29	0.91	-6.93	3.68	-0.001	-2.15	60.15
JPO-3	-1.48	-6.51	1.56**	-0.001	1.73	20.77
JPO-30	2.56*	-6.97	0.77**	-0.001	2.01	51.02
JPO-31	1.21*	-6.96	-1.88	-0.001	2.45	115.80
JPO-35	-0.17	-6.65	0.63**	-0.001	3.12	199.95*
JPO-36	1.35*	-6.98	-1.78	-0.001	2.18	-55.54
JPO-38	1.05**	-6.99	3.18	-0.001	-4.44	68.61
JPO-4	-0.28	-6.77	0.44	-0.001	-1.53	0.46
JPO-40	-0.74	-6.87	-0.86	-0.001	0.18	-39.82
JPO-41	0.91	-6.93	2.52	-0.001	-0.14	-38.27
JPO-44	0.77	-6.77	2.85	-0.001	2.07	58.28
JPO-45	2.10**	-6.99	2.62	-0.001	2.00	103.33
JPO-46	1.81**	-6.98	0.67**	-0.001	-4.43	1388.70**
JPO-5	-0.14	-6.93	1.69**	-0.001	3.96	-24.45
JPO-50	1.66*	-6.90	-0.39	-0.001	-2.37	99.58
JPO-55	1.36	-6.86	-3.97	0.001	3.10	193.81*
JPO-73	4.20*	-6.83	2.62	-0.001	3.39**	-60.60
JPO-8	-0.88	-6.65	-1.65	-0.001	1.34	-9.26
K-353	4.05*	-6.96	1.79	-0.001	5.22	395.16**
KRR-AK-06	0.45	-6.97	1.93**	-0.001	-3.00	-56.62
KRR-AK-15	0.91	-6.93	-3.17	0.000	4.98	-39.92
KRR-AK-26	1.95*	-6.96	-1.55	-0.001	2.32	-46.69
KRR-AK-36	1.66*	-6.90	0.07	-0.001	-0.53	215.44*
KRR-AK-42	-1.62	-6.13	1.79	-0.001	0.16	176.92*
KUE	3.30*	-6.94	2.99	-0.001	0.17	-59.79
No. 77	1.35*	-6.98	0.30**	-0.001	-1.99	-0.23
Oats-102	-0.28	-6.77	-0.95	-0.001	4.68*	-60.34
Oats-17	1.51*	-6.97	1.10**	-0.001	3.26	-41.49
Oats-79	3.30*	-6.94	2.02	-0.001	0.28	236.85*
Oats-80	-2.22	-5.91	3.08	-0.001	1.86	-58.53
Oats-8655	2.10**	-6.99	3.08	-0.001	1.73	427.90**
Oats-902	1.36	-6.86	-4.33	0.001	1.26	-21.29
OG-77	0.45	-6.97	1.33**	-0.001	-0.30	74.23

Genotypes	Flag leaf area (cm^2)		Leaf: stem ratio		Green fodder yield/plant (g)	
	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})	(b_i)	(S^2_{di})
OL-125	1.21*	-6.96	5.07	0.000	-1.82	207.64*
OL-161	2.55*	-6.91	2.49	-0.001	0.39	-57.16
OL-822	1.35*	-6.98	3.88	-0.001	2.04	247.36*
OL-9	1.65*	-6.97	0.67**	-0.001	7.19	1353.94**
OS-10	2.26*	-6.95	4.81	0.000	-1.13	-25.09
OS-121	-0.58	-6.72	2.85	-0.001	-1.44	-51.81
OS-9	0.91	-6.93	-5.82	0.002	1.68	150.40
OS-92	1.05**	-6.99	0.77**	-0.001	2.62	130.34
PO-1	1.66*	-6.90	3.68	-0.001	-0.67	208.44*
S8-217	1.81*	-6.98	1.69**	-0.001	2.40	-45.39
Sabzar	2.25*	-6.94	-1.19	-0.001	6.08	210.58*
SK-150	1.51*	-6.97	-4.80	0.001	-5.36	34.53
SK-199	2.26*	-6.95	-1.09	-0.001	-1.90	39.42
SKO-28	0.01	-6.82	2.85	-0.001	1.41	-6.88
SNTM-90	1.51*	-6.97	4.15	-0.001	-2.58	899.99**
TRS-106	1.21*	-6.96	1.23**	-0.001	-3.36	64.99
UPO-102	0.91	-6.93	2.06**	-0.001	3.33	480.89**
UPO-102-1649	1.07	-6.82	3.78	-0.001	3.87	383.03**
UPO-119	0.77	-6.77	2.52	-0.001	3.78	-24.62
UPO-130	-1.92	-6.02	6.10	0.000	3.32	-32.20
UPO-30	-0.13	-6.58	2.39	-0.001	-2.18	64.78
Kent (C)	0.67	-3.30	-1.32	-0.001	-1.47**	-60.60
OS-6 (C)	0.40	-4.71	-1.57	-0.001	2.28	-51.39
PLP-1 (C)	-0.25	46.66**	2.23	0.002	-0.32	-47.90
RO-19 (C)	2.31	44.85**	0.56**	-0.001	-1.89	282.03*
UPO-212 (C)	0.86	92.90**	-0.39	-0.001	2.52	55.30
Grand mean	1.00	-	1.00	-	1.00	-
S.E (m) ±	0.58	-	0.66	-	2.30	-

*,**Significance at 5 and 1% of deviation regression from zero in case of **S^2_{di} (mean square deviation)** and of regression coefficient from unity in case of **b_i (regression coefficient)**.

responsive for favourable conditions were JHO-862 and KRR-AK-06. Regarding tillers per plant, the mean values ranged from 4.54-12.17 with an average value of 8.37. Genotypes, JPO-31, IGO-14, No.-77 and JPO-41 with above average performance of 10.67, 9.71, 9.08 and 9.04 tillers per plant, were found stable under all the types of environments. The most responsive genotypes Oats-80 and JPO-5 were observed to perform better under favourable environmental conditions for this trait. For flag leaf area, the mean value ranged from 11.75-60.00 cm^2 with an average value of 32.09 cm^2 and genotypes JPO-44 (45.50 cm^2), IG-03-247 (36.83 cm^2), EC-528913 (36.67 cm^2) and JPO-41 (35.33 cm^2) were found stable under all the types of environments. For leaf: stem ratio, the mean value ranged from 0.26-0.48 with an average value of 0.37 and genotypes IG-03-250 (0.48), JPO-30 (0.42) and JPO-46 (0.40) were found suitable and stable over all the environments. Based on significance of regression coefficient (b_i>1), the most responsive geno-types for flag leaf area (JPO-28, K-353 & JPO-73) and leaf: stem ratio (UPO-102 and ADG-2140) were identified. For the major character *i.e.* green fodder yield, the mean value ranged from 78.75-150.83 g with an average value of 115.45 g and only four genotypes, SKO-28 (126.88 g), JHO-822 (126.46 g), Oats-902 (122.21 g) and IG-03-214 (118.33 g) were found stable with b_i values approaching to unity and non-significant S^2_{di} values (Table 4). Six genotypes, IG-03-208, EC-523890, Oats-102, JPO-73, EC-605837 and IG-03-254 showed significant b_i values (b_i>1) were specifically adapted to most favorable environmental conditions depicting that even a small change in environment may result a large increase in response in these genotypes. Thus the present results indicated that there was sufficient variation for performance of the genotypes under different environments. This was also in confirmation with the findings of Kumar *et al.* (1982), Thaware *et al.* (1992), Kishor *et al.* (1994), Lorencetti *et al.* (2002) and Altaf *et*

Table 4. 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
	Poor performing	Best performing	Most responsive	Least responsive	
Plant height	JPO-40	ADG-96	EC-528883, JPO-19, IG-03-48	HJ-8, OS-9	JPO-35, H-B-8, KRR-AK-06, Chorripatli, EC-528865, Kent, IG-03-251, JHO-862 and JHO-99-2
Leaves per plant	EC-605838	IG-03-211	JHO-862, KRR-AK-06	IG-03-247	IG-03-254, JPO-29, JPO-19, IG-03-213, JPO-41 and OS-121
Tillers per plant	EC-605838	IG-03-211	Oats-80, JPO-5	EC-605834	JPO-31, IGO-14, No.-77 and JPO-41
Flag leaf area	JPO-28	JPO-19	JPO-28, K-353, JPO-73	EC-528913	JPO-44, IG-03-247, EC-528913 and JPO-41
Leaf: stem ratio	IG-03-250	OS-92	UPO-102, ADG-214	IG-03-208	IG-03-250, JPO-30 and JPO-46
Green fodder yield	EC-528865	IG-03-211	IG-03-208, EC-523890	Kent, EC-605832	SKO-28, JHO-822, Oats-902 and IG-03-214

al. (2003) where the genotypes showed varied response with the changing environments, accepting existence of genetic variability among the genotypes.

Conclusion

The genotypes *viz.,* SKO-28, JHO-822, Oats-902 and IG-03-214 were found as stable and well adapted to all types of environments for green fodder yield. Hence, these genotypes may be included in any breeding programme where objective is to develop high yielding and stable genotypes over environments. Also these stable genotypes may further be tested at multi-locations to be released as a variety under north-western Himalayan conditions.

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