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Cause and effect relationship among seed and fodder yield traits in wild and cultivated oat

Sawan Kumar*, V.K. Sood, Sanjay Kumar Sanadya, Gaurav Sharma and Ritesh Kaushal

Department of Genetics and Plant Breeding, College of Agriculture
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, India.

*Corresponding author: sawanmehla1993@gmail.com

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Abstract

Present investigation was carried out during *Rabi*, 2018-19 to estimate cause and effect relationship among seed and fodder yield traits in eight accessions of *Avena* species including seven wild *viz*., *A. barbata* (HFO-58), *A. orientalis* (HFO-103), *A. byzantina* (HFO-498) and *A. strigosa* (HFO-505), *A. byzantina* (HFO-60), *A. sterilis* (HFO-508), *A. sterilis* (HFO-878) and one cultivated namely *A. sativa* (HJ-8). The accessions were evaluated in a randomized block design with three replications. Analysis of variance revealed significant differences among the accessions for all the traits studied. High heritability associated with high genetic advance was recorded for most of the traits suggesting the role of additive gene action. Number of tillers per plant, dry matter yield per plant, biological yield per plant, harvest index, seed length and protein content (%) showed significant association with seed yield per plant. Days to 50% flowering, leaf area, plant height, green fodder yield per plant, biological yield per plant, harvest index, seed length and 1000 gain weight had substantial direct effects on seed yield per plant. On the basis of overall performance, HFO-498 (*A. longiglumis*), HFO-505 (*A. strigosa*) and HFO-878 (*A. sterilis*) accessions of wild species were found to be superior over the cultivated *A. sativa*. Thereby, suggesting that these accessions can be utilized in oat improvement programme in near future.

Key words: correlation, oat, Avena, path analysis, variability

Oat (*Avena sativa* L.) is an important forage annual crop of *Rabi* season, possesses wide adaptability and suitability to different growing conditions, excellent nutritional value for both animal as well as human consumption and therefore, it provides an opportunity to use as a dual-purpose crop. Green fodder contains approximately 10 to 13% protein and 30 to 35% dry matter. The protein substance of the hull-less oat (groat) ranges from 12 to 24 per cent, which is the most elevated among cereals (Lasztity 1999). All over the world, oat is cultivated over 10.29 million hectares with a production of 20.49 million tonnes (Anonymous, 2017). The total area covered under oat cultivation in the country is about 1.0 million ha with 35-50 tonnes/ha green fodder productivity (Anonymous, 2014). In India, it is grown in Punjab, Haryana, Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra and West Bengal. Oat within the regions of Himalayas incorporates a more extensive flexibility, since of its great developing environment, speedy re-growth and superior wholesome esteem (Sood *et al*. 2016).

The genus *Avena* comprises about 70 species; a few are cultivated. Wild species such as *A. barbata*, *A. strigosa* and *A. sterilis* related to cultivated crops often contain useful genetic variation for various important traits. Yield is associated with the number of other component traits that are interrelated (Ikeda *et al*., 2013; Zhou *et al*., 2018). Examining the relationship between quantitative traits is an important task of assessing the feasibility of a joint selection of two or more secondary component traits as genetic gains for primary traits under consideration (Ezeaku and Muhammad, 2006). Path analysis is a statistical tool that has been used to organize and present causal relationships between prediction variables and response variables through a path chart based on experimental results (Samonte *et al*., 1998; Esmail, 2001). Often this is dependent on its relationship to the grain yield, which makes the relationship ineffective.

Therefore, path analysis is needed that dividing the correlation coefficient into its direct and indirect effect components (Surek and Beser, 2003). Keeping in view the above mentioned reasons, the present investigation was undertaken to study the cause and effect of relationship among various fodder and seed yield traits in oat.

Materials and methods

Eight accessions of wild *Avena spp*. including seven wild and one cultivated were evaluated for various fodder and seed yield traits during *Rabi*, 2018-19 at Fodder Section Farm, CSKHPKV, Palampur (Table 1). The experimental material was grown in randomized block design with three replications and plot size of 2.00 m × 0.90 m in two rows. Row to row and plant to plant spacing was 30 cm and 10 cm, respectively. Flanking plots were developed using the border rows. One row was used for recording observation on fodder yield traits and second row was used for recording observation on seed yield and its components. The data was recorded on five randomly selected plants in each replication for sixteen different agro-morphological and quality characters. The analysis of variance was carried out as per Panse and Sukhatme (1985).

The genotypic and phenotypic coefficients of variation were estimated following Burton and De Vane (1953). Heritability in a broad sense (h^2_{bs}) and genetic advance (% of mean) were calculated as procedure given by Burton and De Vane (1953) and Johnson et al. (1955). Phenotypic and genotypic coefficients of correlation were worked out following the procedure of Al-Jibouri *et al*. (1958) and Dewey and Lu (1959). Direct and indirect effects of component characters on seed yield per plant were computed using appropriate correlation coefficient of different component characters as suggested by Dewey and Lu (1959).

Results and Discussion

Analysis of Variance

Analysis of variance revealed significant variability among various traits studied except biological yield per plant, days to 75% maturity and green fodder yield/ plant (Table 2).

The mean values for all the sixteen traits studied have been given in Table 3. Cultivated *A. sativa* cv. HJ-8 was used as standard check to compare the mean values of different characters in the present study. As the earliness is desirable character, two accessions *viz*., HFO-498 and HFO-505 were found to have significantly lower days to 50% flowering than HJ-8 (135.67 days). Other remaining accessions were statistically at par with HJ-8 for this trait. Plant height is desirable for fodder yield as it increases the production of green fodder yield. Three accessions of different species were significantly higher in plant height than cultivated HJ-8. The highest value of plant height was recorded for HFO-505 (151.67 cm), followed by HFO-58 (149.67 cm) and HFO-878 (152 cm) as compared to cultivated variety HJ-8 (139.67 cm).

For leaves per plant, all the wild accessions were significantly superior over cultivated *A. sativa* cv. HJ-8 (25.33). The range for leaves per plant was 25-36. Two accessions namely, HFO-60 and HFO-498 were significantly superior over HJ-8 for number of tillers/plant. All the remaining accessions were at par with HJ-8 for this trait. Only one accession i.e. HFO-508 (47.40 g) had significantly higher 1000 grain

Table 1. Details of the material used in the present study

Sr. No.	Species	Accession	Chromosome number (2n)	Source
1.	*Avena orientalis*	HFO 103	14	CCS HAU, Hisar
2.	*Avena longiglumis*	HFO 498	14	CCS HAU, Hisar
3.	*Avena strigosa*	HFO 505	14	CCS HAU, Hisar
4.	*Avena barbata*	HFO 58	28	CCS HAU, Hisar
5.	*Avena byzantina*	HFO 60	42	CCS HAU, Hisar
6.	*Avena sterilis*	HFO 508	42	CCS HAU, Hisar
7.	*Avena sterilis*	HFO 878	42	CCS HAU, Hisar
8.	*Avena sativa*	HJ-8	42	CSKHPKV, Palampur

Table 2. Analysis of variance for different characters in oat wild accessions

Source	Replication	Genotypes	Error
Degree of freedom	2	7	14
Days to 50% flowering	9.44	189.38**	18.33
Plant height (cm)	89.04	138.42**	15.14
No. of Tillers/ plant	1.04	5.61**	1.13
No. of leaves per plant	12.56**	27.31**	1.20
Leaf Area (cm^2)	15.72	305.52**	6.25
Green fodder yield/ Plant (g)	25.83	396.09	96.99
Leaf: stem ratio	0.01	0.03**	0.01
Dry matter yield per plant	2.41	51.54**	7.56
Days to 75% maturity	89.11	58.86	37.23
Spiklets per panicle	1.26	543.19**	26.72
Biological yield per plant	6.25	1489.06**	13.29
Seed yield per plant (g)	5.91	145.16**	7.64
Harvest Index	3.11	82.31**	5.69
Seed length (mm)	0.13	5.94**	0.16
1000 gain wt. (gm)	7.79	78.16**	1.98
Protein Content (%)	0.73	2.15	0.88

*Significant at $p \geq 0.05$, **Significant at $p \geq 0.01$

weight than HJ-8 (44.8 g). In case of seed length, all accessions were recorded significantly higher value than HJ-8 except HFO-508, which was at par with HJ-8 (11.97 mm). Two accessions *viz*., HFO-58 (81.67) and HFO-103 (84.67) were found statistically superior for spikelets per panicle over check variety HJ-8 (62.32). The range for this character was recorded 55.59-84.67. Screening of wild oat germplasm for important agronomical traits had been reported earlier by Sood *et al*. (2016); Jan *et al*. (2020) and Kumar *et al*. (2021). For green fodder yield per plant, HFO-58 (130.33 g), HFO-103 (129.34 g) and HFO-878 (128.34 g) showed significant superiority over HJ-8 (111.05 g). Green fodder yield per plant ranged from 104.33 g to 130.33 g. The lowest green fodder yield was recorded for HFO-508 (104.33 g). All the accessions except HFO-508 had significant higher leaf: stem ratio than HJ-8 (0.38). Leaf: stem ratio ranged from 0.38 to 0.63.

Only one accession i.e. HFO-505 (163.67 days) had been shown significantly lower days to 75% maturity as compared to HJ-8 (175 days). The days to 75% maturity was ranged from 163.67 to 176 days. For dry matter yield per plant, two accessions namely, HFO-498 (35.12 g) and HFO-505 (34.05 g) had higher value than HJ-8 (29.26 g). The mean value for this character was laid between 26.42 g to 35.12 g. For seed yield per plant, HFO-60 (38.19 g), HFO-498 (40.24 g) and HFO-505 (35.77 g) were significantly superior to *A. sativa* cv. HJ-8 (28.80 g). The range for this trait was observed 18.55 g to 40.24 g. When compared with *A. sativa* cv. HJ-8, three accessions namely, HFO-58, HFO-103 and HFO-505 had significantly higher biological yield per plant. While, three accessions were statistically inferior to HJ-8 for this trait. The range of biological yield per plant was 93.88 - 158.24 g. Two accessions were recorded significantly higher harvest index than HJ-8 (22.19). The harvest index was ranged from 19.72 to 35.58. Whereas, two accessions i.e. HFO-103 and HFO-505 were found significantly superior for leaf area over HJ-8. For protein content (%), only two accessions i.e. HFO-58 and HFO-498 were significantly superior as compared to cultivated variety HJ-8.

On the basis of overall performance and earliness, it is concluded that *Avena longiglumis* (HFO-498), *Avena strigosa* (HFO-505) and *A. sterilis* (HFO-878) were significantly superior over the cultivated *Avena sativa* cv. HJ-8 for most fodder and seed yield related components. So, these wild accessions can be used in

Table 3. Mean performance of wild and cultivated Avena species for various fodder and seed yield traits during Rabi, 2018-19

Character Accessions	Days to 50% flowering	Plant Height (cm)	No. of Leaves/ plant	No. of Tillers/ plant	Leaf Area (cm2)	Spiklets per panicle	Green fodder yield/ Plant (g)	Leaf: stem ratio	Dry matter yield per plant	Days to 75% maturity	Biological yield per plant	Seed yield per plant (g)	Harvest Index	1000 grain wt. (g)	Seed length (mm)	Protein Content (%)
HFO 58	135.33	149.67	31.00	11.00	30.40	81.67	130.33	0.56	28.11	173.00	150.53	33.16	22.02	34.40	14.10	9.96
HFO 60	137.67	144.67	30.33	13.00	27.03	69.60	107.67	0.44	31.09	174.33	130.49	38.19	29.33	41.80	15.14	8.39
HFO 103	131.00	137.00	29.00	12.00	54.27	84.67	129.34	0.47	28.96	169.33	158.24	33.19	20.97	34.00	14.02	8.81
HFO 498	123.00	134.67	28.33	14.33	25.83	70.39	105.33	0.56	35.12	166.67	113.13	40.24	35.58	42.90	14.09	9.69
HFO 505	120.00	151.67	29.67	11.67	37.13	43.24	124.00	0.63	34.05	163.67	140.10	35.77	25.52	36.10	14.17	8.93
HFO 508	142.00	140.33	36.00	12.00	21.47	55.59	104.33	0.41	22.17	176.33	105.38	27.04	25.65	47.40	12.28	7.58
HFO 878	140.33	152.00	31.00	10.00	31.47	69.26	128.34	0.63	26.42	173.00	93.88	18.55	19.72	43.70	11.03	8.27
HJ 8	135.67	139.67	25.33	10.67	28.23	62.32	111.05	0.38	29.26	175.00	129.86	28.80	22.19	44.80	11.97	7.77
Mean	133.13	143.71	30.08	11.83	31.98	67.09	117.55	0.51	29.40	171.42	127.70	31.87	25.12	40.64	13.35	8.68
S.E.	2.47	2.25	0.63	0.61	1.44	2.98	5.69	0.02	1.59	3.52	2.10	1.60	1.38	0.81	0.23	0.54
CD (5%)	7.52	6.83	1.93	1.87	4.39	9.07	17.29	0.05	4.83	10.71	6.40	4.85	4.19	2.47	0.71	1.64
CV (%)	3.22	2.71	3.65	8.98	7.82	7.70	8.38	6.08	9.35	3.56	2.85	8.67	9.49	3.46	3.03	10.78

further breeding programme to introgress desirable traits into cultivated oat cultivars.

Estimates of genetic parameters for variability

Genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability and genetic advance (% of mean) were calculated and presented in Table 4. The highest value of PCV was recorded for leaf area (32.20%), followed by seed yield per plant (22.95%) and harvest index (22.24%), and seven characters showed the high phenotypic coefficient of variation (≥ 15%) namely spikelets/ panicle, leaf: stem ratio, dry matter yield per plant, biological yield per plant, seed yield/ plant, harvest index and leaf area. Low PCV (≤ 10%) was recorded for plant height (5.22%), days to 50% flowering (6.52%) and days to 75% maturity (3.89). Moderate PCV was observed for remaining six characters.

High value of GCV (≥ 15%) was recorded for six characters *viz*., spikelets/panicle, leaf: stem ratio, seed yield per plant, biological yield per plant, harvest index and leaf area. Highest GCV was found for leaf area (31.23%), followed by seed yield per plant (21.24%), harvest index (20.12%) and spikelets per panicle (19.56%). Low GCV (≤ 10%) was observed for plant height, number of leaves per plant, days to 50% flowering, green fodder yield per plant, days to 75% maturity and protein content. Remaining four traits showed moderate GCV (10-15%). High PCV coupled with high GCV was recorded for spikelets per panicle, leaf:stem ratio, seed yield per plant, biological yield per plant, harvest index and leaf area. The broad sense heritability was recorded high (above 70%) for plant height, number of leaves/plant, 1000 grain weight, seed length, spikelets per panicle, days to 50% flowering, leaf: stem ratio, seed yield per plant, biological yield per plant and leaf area. Moderate heritability (50-70%) was shown by number of tillers per plant, green fodder yield per plant, dry matter yield per plant, days to 75% maturity and protein content had the low heritability. High heritability coupled with high genetic advance (% of mean) was observed for 1000 grain weight, seed length, spikelets per panicle, leaf: stem ratio, seed yield per plant, biological yield per plant, harvest index and leaf area.

Correlation and path analysis among various fodder and seed yield traits in *Avena* species

In general, genotypic correlation coefficients were greater than their corresponding phenotypic correlation coefficients, indicating the preponderance of genetic variance in expression of characters as well as masking effect of environment in modifying the total expression of the genotypes (Table 5). At phenotypic level, positive significant relationships existed between seed yield and number of tillers per plant, dry matter yield per plant, biological yield per plant, harvest index and seed length, while negatively

Table 4. Estimation of genetic parameters for various studied traits in *Avena* species

Characters	Range	PCV	GCV	Heritability (h^2_{bs})	Genetic Advance (% of mean)
Days to 50% flowering	120.00-142.00	6.52	5.67	75.67	10.16
Plant Height (cm)	134.67-152.00	5.22	4.46	73.08	7.86
No. of Leaves/ plant	25.33-36.00	10.46	9.81	87.84	18.93
No. of Tillers/ plant	10.00-14.33	13.69	10.33	56.94	16.05
Leaf Area (cm^2)	21.47-54.27	32.20	31.23	94.10	62.41
Spiklets per panicle	43.24-84.67	21.02	19.56	86.57	37.48
Green fodder yield/ Plant (g)	104.33-130.33	11.93	8.49	50.69	12.46
Leaf: stem ratio	0.38-0.63	19.84	18.89	90.61	37.04
Dry matter yield per plant	22.17-35.12	16.04	13.02	65.97	21.79
Days to 75% maturity	163.67-176.33	3.89	1.57	16.23	1.30
Biological yield per plant	93.88-158.24	17.60	17.37	97.37	35.30
Seed yield per plant (g)	18.55-40.24	22.95	21.24	85.71	40.52
Harvest Index	19.72-35.58	22.24	20.12	81.78	37.47
Seed length (mm)	11.03-15.14	10.83	10.39	92.17	20.56
1000 gain wt. (g)	34.00-47.40	12.88	12.40	92.76	24.60
Protein Content (%)	7.58-9.96	13.15	7.53	32.77	8.88

Table 5. Estimation of Phenotypic (upper diagonal) and Genotypic (lower diagonal) correlation coefficient for various fodder and seed yield traits in oat

Characters	Days to 50% flowering	No. of Leaves/ plant	No. of Tillers/ plant	Leaf area	Leaf: stem ratio	Plant height	Green fodder yield/ plant	Dry matter yield / plant	Days to 75% maturity	Spikelets per panicle	Biological yield per plant	Harvest Index	Seed length	1000 grain wt	Protein content	Seed yield per plant
Days to 50% flowering	**1.000**	0.399	-0.338	-0.257	-0.407*	0.113	-0.022	-0.664**	0.518**	0.220	-0.305	-0.431*	-0.498*	0.444*	-0.277	-0.583**
No. of Leaves/ plant	0.483*	**1.000**	-0.003	-0.262	0.034	0.172	-0.063	-0.617**	0.197	-0.159	-0.313	-0.037	-0.096	0.210	-0.179	-0.251
No. of Tillers/ plant	-0.549**	-0.007	**1.000**	-0.109	-0.042	-0.381	-0.259	0.462*	-0.005	-0.026	0.046	0.666**	0.552**	0.051	0.387	0.614**
Leaf area	-0.374	-0.314	-0.159	**1.000**	0.186	-0.026	0.597**	0.150	-0.326	0.348	0.653**	-0.423*	0.185	-0.697**	0.211	0.063
Leaf: stem ratio	-0.519**	0.043	-0.160	0.164	**1.000**	0.572**	0.471*	0.325	-0.337	-0.087	-0.090	-0.006	0.013	-0.396	0.520**	-0.038
Plant height	0.094	0.260	-0.797**	-0.054	0.631**	**1.000**	0.504*	-0.012	-0.023	-0.190	-0.040	-0.461*	-0.132	-0.212	0.152	-0.383
Green fodder yield/ plant	-0.150	-0.114	-0.922**	0.766**	0.652**	0.623**	**1.000**	0.119	-0.093	0.284	0.401	-0.617**	-0.072	-0.583**	0.360	-0.256
Dry matter yield per plant	-1.007**	-0.678**	0.581**	0.190	0.407*	-0.144	-0.180	**1.000**	-0.391	-0.092	0.275	0.476*	0.504*	-0.350	0.502*	0.630**
Days to 75% maturity	1.744**	0.534**	-0.979**	-0.701**	-1.212**	-0.097	-0.607**	-1.489**	**1.000**	0.022	-0.203	-0.148	-0.237	0.281	-0.189	-0.275
Spikelets /panicle	0.269	-0.155	0.092	0.381	-0.088	-0.319	0.409*	-0.097	0.535**	**1.000**	0.318	-0.169	0.128	-0.328	0.316	0.034
Biological yield per plant	-0.403	-0.369	0.022	0.653**	-0.104	-0.051	0.487*	0.329	-0.471*	0.346	**1.000**	-0.198	0.602**	-0.811**	0.362	0.499*
Harvest Index	-0.466*	-0.031	1.116**	-0.449*	-0.004	-0.447*	-0.800**	0.642**	-0.637**	-0.179	-0.212	**1.000**	0.474*	0.213	0.156	0.747**
Seed length	-0.514*	-0.111	0.752**	0.245	0.052	-0.124	-0.036	0.673**	-0.775**	0.209	0.666**	0.537**	**1.000**	-0.568**	0.311	0.841**
1000 grain wt	0.495*	0.211	0.052	-0.774**	-0.415*	-0.285	-0.894**	-0.375	0.980**	-0.400	-0.871**	0.285	-0.587**	**1.000**	-0.463*	-0.365
Protein content	-0.909**	-0.218	0.284	0.221	0.689**	0.013	0.412*	0.663**	-1.440**	0.545**	0.525**	0.451*	0.867**	-0.913**	**1.000**	0.381
Seed yield per plant	-0.701**	-0.297	0.958**	0.072	-0.053	-0.358	-0.336	0.817**	-0.905**	0.062	0.534**	0.710**	0.960**	-0.388	0.755**	**1.000**

*Significant at $p \leq 0.05$, **Significant at $p \leq 0.01$

significant was found for days to 50% flowering. At genotypic level, positive significant relationships existed between seed yield and number of tillers per plant, dry matter yield per plant, biological yield per plant, harvest index, seed length and protein content, whereas, negatively significant correlation was found for days to 50% flowering and days to 75% maturity. Similar results of correlation were reported by Bibi *et al*. (2012), Ahmad *et al*. (2013), Gautam *et al*. (2006) and Sakhale *et al*. (2014).

Path analysis showed that days to 50% flowering, leaf area, plant height, green fodder yield per plant, biological yield per plant, harvest index, seed length, 1000 grain weight and protein content had strong positive direct effects on the seed yield per plant (Table 6). However, the correlation between number of tillers per plant and the seed yield per plant was significantly negative due to their strong negative indirect effects via harvest index and seed length. Dubey *et al*. (2014), Jaipal and Shekhawat (2016) and Arora *et al*. (2021) had reported similar findings in oat.

In conclusion, significant differences were obtained among the accessions of Avena species, which reflects ample amount of genetic variability existed in the experimental material. High PCV coupled with high GCV were recorded for spikelets per panicle, leaf: stem ratio, seed yield per plant, biological yield per plant, harvest index and leaf area. High heritability coupled with high genetic advance was recorded for 1000 grain weight, seed length, spikelets per panicle, leaf: stem ratio, seed yield per plant, biological yield per plant, harvest index and leaf area indicated that these were under the control of additive gene effects and selections based on the traits could improve productivity in oat directly. The information from correlation and path coefficient analysis in oat will be helping in finding out the structural yield components that can be appropriately incorporated into an improved plant type. On the basis of overall performance, HFO-498 (*A. longiglumis*), HFO-505 (*A. strigosa*) and HFO-878 (*A. sterilis*) accessions of wild species were found significantly superior over the cultivated A. sativa cv. HJ-8. Therefore, these accessions can be utilized in oat improvement programme in near future.

Conflict of interest: The authors would hereby like to declare that there is no conflict of interests that could possibly arise.

Table 6. Direct (diagonal) and indirect effects (non-diagonal) of different characters on seed yield per plant in oat

Characters	Days to 50% flowering	No. of Leaves/ plant	No. of Tillers/ plant	Leaf area	Leaf: stem ratio	Plant height	Green fodder yield/ plant	DMY / plant	Days to 75% maturity	Spikelets per panicle	Biological yield per plant	Harvest Index	Seed length	1000 grain wt	Protein content	Seed yield per plant
Days to 50% flowering	**0.085**	-0.060	0.015	-0.024	0.015	0.006	-0.011	0.092	-0.012	-0.026	-0.246	-0.447	-0.080	0.009	-0.016	-0.701**
No. of Leaves/ plant	0.041	**-0.124**	0.000	-0.020	-0.001	0.015	-0.009	0.062	-0.004	0.015	-0.225	-0.030	-0.017	0.004	-0.004	-0.297
No. of Tillers/ plant	-0.047	0.001	**-0.026**	-0.010	0.005	-0.047	-0.070	-0.053	0.007	-0.009	0.014	1.072	0.116	0.001	0.005	0.958**
Leaf area	-0.032	0.039	0.004	**0.064**	-0.005	-0.003	0.058	-0.017	0.005	-0.037	0.399	-0.431	0.038	-0.013	0.004	0.072
Leaf: stem ratio	-0.044	-0.005	0.004	0.011	**-0.029**	0.037	0.049	-0.037	0.008	0.009	-0.064	-0.004	0.008	-0.007	0.012	-0.053
Plant height	0.008	-0.032	0.021	-0.003	-0.018	**0.059**	0.047	0.013	0.001	0.031	-0.031	-0.429	-0.019	-0.005	0.000	-0.358
Green fodder yield/ plant	-0.013	0.014	0.024	0.049	-0.019	0.037	**0.075**	0.016	0.004	-0.040	0.297	-0.769	-0.006	-0.016	0.007	-0.336
DMY per plant	-0.086	0.084	-0.015	0.012	-0.012	-0.009	-0.014	**-0.091**	0.010	0.009	0.201	0.617	0.104	-0.007	0.012	0.817**
Days to 75% maturity	0.148	-0.066	0.026	-0.045	0.035	-0.006	-0.046	0.135	**-0.007**	-0.052	-0.288	-0.612	-0.120	0.017	-0.025	-0.905**
Spikelets per panicle	0.023	0.019	-0.002	0.024	0.003	-0.019	0.031	0.009	-0.004	**-0.097**	0.211	-0.172	0.032	-0.007	0.010	0.062
Biological yield per plant	-0.034	0.046	-0.001	0.042	0.003	-0.003	0.037	-0.030	0.003	-0.033	**0.611**	-0.204	0.103	-0.015	0.009	0.534**
Harvest Index	-0.040	0.004	-0.030	-0.029	0.000	-0.027	-0.060	-0.058	0.004	0.017	-0.129	**0.961**	0.083	0.005	0.008	0.710**
Seed length	-0.044	0.014	-0.020	0.016	-0.001	-0.007	-0.003	-0.061	0.005	-0.020	0.407	0.516	**0.155**	-0.010	0.015	0.960**
1000 grain wt	0.042	-0.026	-0.001	-0.050	0.012	-0.017	-0.067	0.034	-0.007	0.039	-0.532	0.274	-0.091	**0.017**	-0.016	-0.388
Protein content	-0.077	0.027	-0.008	0.014	-0.020	0.001	0.031	-0.060	0.010	-0.053	0.320	0.434	0.134	-0.016	**0.018**	0.755**

*Significant at $p \leq 0.05$, **Significant at $p \leq 0.01$

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