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VARIABILITY AND CAUSE EFFECT ANALYSIS FOR FODDER AND GRAIN YIELD CHARACTERS IN OAT (*AVENA SATIVA* L.) GENOTYPES

D. T. SURJE*, SWARNAJIT DEB BARMA, S. B. SATPUTE[1], V. A. KALE, APARAJITA DAS AND D. K. DE[2]

Department of Genetics & Plant Breeding
Uttar Banga Krishi Viswavidyalaya,
Pundibari, Cooch Behar-736 165 (West Bengal), India
(e-mail : dinosurje@gmail.com)

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SUMMARY

A field experiment was conducted at the Central Research Farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal during 2009-10 to estimate the mean performance of yield and other morpho-physiological characters and also to determine their effects (direct and indirect) towards yield (fodder and grain yield). Considering green forage yield, and dry matter yield, it was observed that the genotype NOD-609 produced the highest and significantly higher mean for both the characters. However, considering the mean values for different characters of cut and uncut management of oat genotype Kent and JHO-99-2 had highest total grain yield per plant and number of grains per panicle. Path analysis was carried out considering grain yield as the dependent variable. Chlorophyll 'b' content showed highest positive direct effect towards grain yield where one cut was practised at 55 days of the crop which was followed by chlorophyll 'a' content, number of grains per panicle, crude protein (%), length of panicle, tiller number per plant and weight of flag leaf. But when no cut was practised, characters like number of grains per panicle, green forage yield per plant, total chlorophyll content, tiller number per plant, number of spikelets per panicle, 100-seed weight and length of panicle had direct effect towards grain yield.

Key words : Variability, path analysis, fodder, oat, yield

India possesses a large bovine population which includes 200 million cattle and 92 million buffalo. This accounts for 19.5 per cent of the global cattle population. Despite this large bovine population, the scenario of milk production and productivity is far below the world average. The supply of nutritious fodder is a pre-requisite for the success of any dairy industry (Arun Kumar *et al.*, 2010). The availability of nutritive fodder in this country is inadequate. Majority of farmers feed fodder with little concentrate or even with fodder only. Therefore, the demand for fodder will keep on increasing. Oat is nutritive and palatable forage having good regenerating capacity with high dry matter production. It can be grown on variety of soils. Oat crop is a heavy yielder and the average yield varies from 45 to 55 tonnes of green fodder per hectare. The total area covered under oat cultivation in the country is about 5,00000 ha. Oat has assured considerable importance in India as fodder as well as grain for animal feed particularly calves and young stocks, horses, poultry and sheep. In dairy farms, oat as a fodder is inevitably adopted, as it can be fed green and surplus converted into silage or hay for use during the lean period. Despite the extensive worldwide use of oat for forage and fodder uses, very little of the world's research plant improvement resources are devoted to the development of the oat crop specifically for fodder uses. When more characters are included in correlation study the indirect association becomes complex. In such situation, the path coefficient analysis is suggested by Dewey and Lu (1959) which provides a means of untangling the complex correlation into direct and indirect effects of the component characters of yield so as to find out the efficient characters contributing effectively towards the yields. Thus, the present study

[1]Department of Agronomy.
[2]Department of Plant Breeding, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741 252 (West Bengal), India.

was undertaken to estimate the variability in germplasm and other standard varieties of *Avena sativa* sp. for different fodder and grain yield characters.

MATERIALS AND METHODS

The field experiment was conducted at the Central Research Farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal during 2009-10. The experimental material for present investigation comprised 15 diverse forage genotypes of oat (*Avena sativa* L.) (Table 1). The experiment was conducted in randomized block design (RBD) with three replications. The plot size for each genotype in each replication was 3.0 × 3.0 m. Each plot accommodated 12 rows of 3 m length at a distance of 25 cm from row to row. The fertilizer schedule, irrigation and other cultivation aspects were adopted as per recommendations for commercial cultivation of fodder oat. Since the experiment was conducted with fodder oat (*Avena sativa* L.) practising cut and uncut managements data with respect to different morphological and biochemical characters were collected from each of the two different cutting management plants. In each plot of three replications, five plants were selected randomly (cut and uncut plant) separately for collection of data for green forage yield and dry matter yield obtained from cut plants when they were cut at a height of 20 cm from ground was recorded on harvest at 55 days age of the crop, and data for plant height and tiller number were noted from the randomly selected plants before final harvesting of the crop. For collecting data on leaf area, fag leaf weight and chlorophyll analysis the selected flag leaf was collected at flowering from main tillers in each replication. For panicle length, number of grains per spikelet, number of spikelets, 100-seed weight and grain yield per plant were counted after harvesting the panicle from selected plants. Seed was used for estimation of protein content. The path coefficient analysis was calculated to estimate direct and indirect contribution of characters with five characters as described by Dewey and Lu (1959) at genotypic level.

TABLE 1
Genotypes used in the present experiment

S. No.	Genotypes	Source
1.	NDO-609	Faizabad
2.	SKO-163	Srinagar
3.	JO-03-95	Jabalpur
4.	SKO-156	Srinagar
5.	JHO-99-2	Zonal Check
6.	JHO-2009-1	IGFRI, Jhansi
7.	UPO-09-2	GBPUAT, Pantnagar
8.	OS-6	National Check
9.	SKO-148	Srinagar
10.	UPO-09-1	GBPUAT, Pantnagar
11.	NDO-603	Faizabad
12.	JHO-2009-2	IGFRI, Jhansi
13.	OS-374	Hisar
14.	Kent	National Check
15.	OS-363	Hisar

RESULTS AND DISCUSSION

Since the experiment was conducted in two different modes : one to determine the yield potential of a particular genotype when it is subjected to one cut as fodder and then left to regenerate and produce seed and the other to produce seed only by the respective genotype without taking any cut; therefore, the results have been presented for the two different managements separately.

Mean values of 15 genotypes of oat for yield and other morpho-physiological traits viz., plant height (cm), tiller number per plant, green forage yield, weight of flag leaf (g), length of panicle (cm), number of spikelets per plant, number of grains per panicle, 100-seed weight (g), leaf area (cm^2), chlorophyll content (mg/g fresh tissue), protein content (%), green forage yield and dry matter yield were obtained from plants where one cut was practised at 55 days of the crop and are presented in Table 2.

But when no cut was practised, the characters green forage yield and dry matter yield were not there and the mean values of 15 genotypes of oat for respective traits are presented in Table 3.

Considering the mean values of different characters under the two cutting managements, it was observed that the values generally reduced in all the characters when one cut was practised. However, such reduction of mean varied from genotype to genotype. Some genotypes were much affected due to taking one cut at 55 days age of the crop, while the others were not so much affected. Therefore, a comparative statement of performance is being presented below.

Plant height of some of the genotypes, namely, JO-03-95, NDO-603 and OS-363 was highly affected due to taking one cut, while many of the genotypes did not exhibit any significant reduction in height at final stage of growth even though one cut was taken from them. Some of such genotypes were JHO-99-2, JHO-

TABLE 2

Mean values and critical difference (C. D.) of fifteen genotypes of oat obtained from plants taken as cut

Variables	NDO-609	SKO-163	JO-03-95	SKO-156	JHO-99-2	JHO-2009-1	UPO-09-2	OS-6	SKO-148	UPO-09-1	NDO-603	Kent	OS-374	JHO-2009-2	OS-363	Mean	C. D. (P=0.05)
PH	132.40	71.2	28.45	112.9	166.7	160.8	139.4	132.5	125.7	124.2	138.9	141.2	133.6	134.4	129.8	131.48	2.40
TN	4.167	3.63	4.37	4.00	3.53	4.07	3.87	4.73	4.33	4.93	3.33	5.17	3.73	3.53	4.00	4.09	0.34
GF	4.103	4.07	7.73	6.18	3.94	6.55	5.31	4.52	5.72	4.38	5.31	4.57	3.99	5.45	3.66	5.03	0.07
DM	0.991	0.95	1.49	1.16	1.08	1.27	1.10	0.97	1.19	0.97	1.04	1.06	0.90	1.03	0.87	1.07	0.02
WFL	2.813	2.23	2.12	2.94	2.77	2.99	1.99	2.42	2.74	2.02	2.47	2.04	2.95	1.95	1.67	2.41	0.12
LP	29.23	21.25	20.94	29.4	28.73	28.73	31.14	27.52	28.63	27.35	30.07	34.64	27.97	29.15	30.29	28.43	1.92
NSP	13.26	10.07	12.00	10.07	13.20	11.40	11.87	11.07	10.27	10.27	10.60	12.07	12.53	9.47	14.27	11.49	0.84
NGP	81.07	27.53	66.43	25.73	169.9	57.93	73.27	78.80	56.87	49.57	49.33	102.5	93.67	64.60	69.47	71.12	3.43
HSW	3.20	3.25	3.25	2.79	2.78	3.70	3.74	3.42	3.99	3.90	4.02	3.17	3.22	3.69	3.39	3.43	0.14
FLA	30.67	30.2	21.68	25.08	22.16	32.49	27.76	25.18	36.56	35.68	27.53	26.48	29.82	31.79	24.62	28.47	1.32
CHL a	0.719	0.93	1.03	0.98	1.02	1.21	0.99	1.26	0.99	1.12	0.99	1.18	0.92	0.18	1.02	1.01	0.05
CHL b	0.458	0.57	0.65	0.60	0.62	0.71	0.59	0.67	0.62	0.65	0.65	0.78	0.56	0.51	0.61	0.62	0.03
TCHL	1.176	1.54	1.69	1.57	1.63	1.92	1.58	1.95	1.61	1.77	1.63	1.96	1.49	1.32	1.64	1.63	0.06
CP (%)	9.80	8.92	5.95	6.77	9.10	7.23	10.15	6.12	9.22	12.54	8.92	7.41	9.86	11.26	6.18	8.63	0.36
GY	10.64	3.23	9.25	2.89	16.87	8.69	10.92	12.74	9.66	9.54	6.60	17.02	11.43	8.46	9.33	9.18	0.83

PH–Plant height, TN–Tiller numbers/plant, GF–Green forage yield/plant, DM–Dry matter yield/ plant, WFL–Weight of flag leaf, LP–Length of panicle, NSP–Number of spikelets/panicle, NGP–Number of grains/panicle, HSW–100-seed weight, FLA–Flag leaf area, CHL a–Chlorophyll a, CHL b–Chlorophyll b, TCHL–Total chlorophyll, CP%–Crude protein (%) and GY–Grain yield/plant.

TABLE 3

Mean values and critical difference (C. D.) of fifteen genotypes of oat obtained from plants taken as uncut

Variables	NDO-609	SKO-163	JO-03-95	SKO-156	JHO-99-2	JHO-2009-1	UPO-09-2	OS-6	SKO-148	UPO-09-1	NDO-603	Kent	OS-374	JHO-2009-2	OS-363	Mean	C. D. (P=0.05)
PH	147.3	84.90	157.6	131.7	164.6	165.9	160.5	152.4	133.5	126.3	164.4	150.7	136.3	156.8	144.3	145.2	2.84
TN	4.80	3.80	4.07	3.87	4.50	5.53	4.07	4.367	3.80	5.93	4.83	5.20	4.67	5.033	5.733	4.68	0.40
WFL	2.52	2.06	2.07	3.81	2.858	3.08	2.45	3.464	2.90	3.02	1.79	2.87	3.49	2.462	1.630	2.69	0.11
LP	27.80	18.90	26.60	31.37	30.46	31.29	33.54	31.20	29.17	29.99	35.89	32.56	31.63	30.36	28.16	29.93	2.35
NSP	10.07	8.93	13.70	12.40	13.70	14.3	14.1	13.6	13.30	15.90	16.60	16.70	16.40	16.10	16.20	14.10	0.99
NGP	69.20	28.20	125.1	38.60	142.5	103.7	106.3	124.3	100.4	58.7	111.2	156.6	119.9	98.4	118.3	100.1	3.20
HSW	3.60	3.04	2.95	3.23	3.33	3.36	4.07	3.333	3.70	3.760	3.57	3.12	3.42	3.243	3.140	3.39	0.12
FLA	30.82	27.45	29.32	40.21	34.13	39.80	32.12	29.48	26.12	41.2	27.8	40.19	39.47	37.91	25.21	33.42	1.46
CHL a	0.95	1.07	1.21	1.31	1.29	1.31	1.10	1.42	1.24	1.29	1.12	1.47	1.08	1.041	1.274	1.212	0.06
CHL b	0.58	0.63	0.69	0.78	0.69	0.82	0.74	0.85	0.71	0.77	0.68	0.88	0.645	0.621	0.753	0.723	0.06
TCHL	1.53	1.71	1.91	2.09	1.98	2.11	1.81	2.27	1.95	2.06	1.8	2.34	1.720	1.662	2.027	1.932	0.11
CP (%)	9.57	8.12	5.42	7.52	11.61	9.16	10.73	7.76	9.97	12.48	10.33	6.36	7.99	9.217	5.483	8.781	0.49
GY	11.99	3.24	14.99	4.80	21.34	19.27	17.57	18.07	14.11	13.09	19.21	25.21	19.12	16.05	21.22	15.95	1.65

Character details are given in Table 2.

2009-1, SKO-148, UPO-09-1, OS-374 and Kent. Such genotypes may be identified as multicut type of fodder oat.

In case of tiller number per plant, as many as seven genotypes, namely, JHO-99-2, JHO-2009-1, UPO-09-1, NDO-603, OS-374, JHO-2009-2 and OS-363 were highly affected due to taking one cut and the tiller number was reduced, while five genotypes did not exhibit any significant reduction in tiller number at final stage of growth even when one cut was taken. Some of such genotypes were SKO-163, JO-03-95, SKO-156 and UPO-09-2.

Interestingly, in case of fresh weight of flag leaf, it was noticed that in some of the genotypes the fresh weight of flag leaf increased when one cut was practised. Such genotypes were NDO-609, SKO-163, JO-03-95 and NDO-603. On the other hand, the mean value of some of the genotypes remained unchanged even after taking one cut. Some of such genotypes were SKO-156 and JHO-99-2. Again some of the genotypes recorded reduced mean for fresh weight of flag leaf in the plants where one cut was taken. Such genotypes were UPO-09-2, OS-6 and UPO-09-1.

Considering length of panicle and the number of grains per panicle together, two genotypes viz., NDO-609 and SKO-163 produced higher mean for these two characters from the plants where one cut was taken with compared to uncut counterpart, while as many as 11 genotypes out of 15 were affected due to taking one cut of the crop. It may be mentioned here that these two genotypes exhibited increased weight of flag leaf in the regenerated plants when one cut was taken at 55 days of the crop.

In case of number of grains per panicle, it was observed that two genotypes viz., NDO-609 and JHO-99-2 produced higher mean in the plants where one cut was practised, while in as many as 11 genotypes, the number of grains per panicle reduced due to taking one cut. It may be mentioned here that the former genotype produced higher length of panicle and number of seeds per panicle in the regenerated plants where one cut was practised.

Conspicuously, the 100-seed weight increased in the plants of as many as eight genotypes when one cut was practised with compared to those of uncut. It indicates that after taking one cut the plants might have switched on to reproductive phase resulting in such increased 100-seed weight. It may be mentioned that many of such genotypes had reduced mean for length of panicle, number of spikelets per panicle and number of seeds per panicle in the cut plants. Since the translocable photosynthate was already produced therefore each seed could get higher amount of nutrition and consequently higher 100-seed weight. However, the 100-seed weight was reduced in the remaining genotypes.

In case of flag leaf area generally the mean value reduced when one cut was practised. However, in two genotypes viz., SKO-163 and SKO-148 the flag leaf area increased even after taking one cut. This may be due to differential genetic makeup of the genotypes. It may be mentioned here that the former genotype exhibited increased mean for many of the characters including weight of flag leaf when one cut was practised.

All the genotypes except NDO-609 produced lower mean for chlorophyll content when one cut was taken. The same genotype produced higher mean for weight of flag leaf when one cut was practised with compared to that of uncut.

In case of crude protein %, four genotypes exhibited higher mean in the cut plants with compared to those of uncut. However, such genotypes were Kent, OS-374, JHO-2009-2 and OS-363. The remaining genotypes evidenced lower mean crude protein % with compared to those of cut.

Besides green forage yield, grain yield per plant is also an important character in case of fodder crop. It was always found that the grain yield was reduced in different degrees in cut plants with compared to uncut of the respective genotype. According to Hooda *et al*. (1999) cutting management treatment involving no cutting for fodder and harvesting the pearl millet crop for grain only recorded significantly higher grain and stover yield than that of cutting of pearl millet for green fodder at 45 DAS and regenerated crop for grain production. However, the different degree of reduction of grain yield by different genotypes obtained in the present experiment may be attributed to the genetic makeup of that particular genotype.

Interestingly, some of the genotypes exhibited no substantial reduction of plant height even after taking one cut (e. g. JHO-99-2, JHO-2009-1, SKO-148, UPO-09-1, OS-374 and Kent) but such genotypes could not always produce significantly higher green forage yield (e. g. JHO-99-2 and Kent). Most importantly, the common genotypes where both the above two characters exhibited desirable result i. e. no substantial reduction in green fodder after one cut and could produce significantly high green fodder could not produce desirable grain yield.

However, considering seed yield only OS-363, JHO-99-2, JHO-2009-1 and NDO 603 appeared to be the most desirable genotypes. Considering the green forage yield and seed yield UPO-09-2 appeared to be the best genotype. This genotype produced significantly higher mean in six different characters out of 15 characters studied.

The correlation values illustrate the inter-relationship between different characters. Path coefficient splits the interrelationship into direct and indirect effects. Genotypic path analysis was done to establish associations of grain yield attributing characters. The results of correlation have been partitioned into direct and indirect effects through genotypic path coefficient analysis and presented in Table 4 for cut management and in Table 5 for uncut management.

In one experiment, the crop was cut once and was allowed to regenerate and produce seed. Thus, considering grain yield as the dependent variable the path analysis was carried out in the present study. In this case, there were 14 independent variables viz., plant height, tiller number per plant, green forage yield per plant, dry matter per plant, weight of flag leaf, length of panicle, number of spikelets/per plant, number of grains per panicle, 100-seed weight, flag leaf area, chlorophyll content and protein content (%). The direct effect of plant height on grain yield was negative. The indirect effect via green forage yield, number of spikelets per plant, length of panicle and green forage was positive. The positive indirect effects of these characters might have compensated so much so that a significantly positive correlation could be noticed between plant height and grain yield. It may be mentioned here that correlation values at both genotypic and phenotypic levels between spikelets per panicle and length of panicle were positive. The tiller number per plant was found to exhibit positive association with grain yield having correlation value of 0.38. In spite of high and positive direct effect of the green forage yield on seed yield no correlation could be discerned between these two characters. Singh *et al.* (1995) revealed that plant height and tiller number per plant showed direct positive effects on green forage. Similarly, Katiyar and Choudhary (1999) obtained the highest positive contribution of plant height towards green fodder yield. Frey and Wiggens (1957) reported that tillering was an important plant character and might contribute subsequently towards increased forage yield.

It may be mentioned that a genotype which will have luxurious vegetative growth the grain yield is generally reduced. It indicates that at the time of development of the genotype partitioning of photosynthate for the development of sink has not been given much emphasis. Similarly, in case of dry matter yield, a negative direct effect could be recorded with grain yield that was not compensated by high and positive indirect effect of green forage and consequently no correlation could be established. Weight of flag leaf also had no correlation with grain yield. It may be seen from Table 2 that this character had neither high direct effect nor high indirect via any character except green forage yield that could bring about a significant correlation between weight of flag leaf and grain yield. The three reproductive characters revealed high to very high positive direct effect on grain yield. Also some of the ancillary characters like number of grains per panicle and dry matter yield exhibited substantial positive indirect effect on the character resulting in highly significant and positive correlation between length of panicle, number of spikelets per spike, number of grains per spike and grain yield. Flag leaf area in spite of having positive direct effect could not produce any correlation with grain yield. It may be mentioned that a fodder variety is developed giving much emphasis on the characters related to vegetative growth when the seed yield is not taken much care of. Such selection pressure may be one of the reasons for such non-association between flag leaf area and grain yield. In case of chlorophyll ‘a’ and chlorophyll ‘b’ content the direct effects with grain yield were negative. The indirect effects via all the characters except tiller number and total chlorophyll content also were negligible. This might have resulted non-significant correlation. Crude protein content also had very low direct and indirect effects of other characters consequently no correlation could be established.

In another experiment, path analysis was carried out considering grain yield as the dependent variable where one cut was practised at 55 days of the crop. In these cases, there were 12 independent variables viz., plant height, tiller number per plant, weight of flag leaf, length of panicle, number of spikelets per panicle, number

TABLE 4

Direct and indirect effects of component characters on grain yield per plant practised as cut

Effect of characters	PH	TN	GF	DM	WFL	LP	NSP	NGP	HSW	FLA	CHL a	CHL b	TCHL	CP (%)	GY
PH	**-0.538**	0.004	0.109	-0.167	0.012	0.114	0.123	0.999	0.015	-0.010	-0.026	-0.395	0.089	-0.002	0.68**
TN	-0.007	**0.335**	0.046	-0.086	-0.012	0.036	0.001	-0.008	0.007	0.007	-0.057	-0.077	0.212	-0.013	0.38*
GF	-0.054	0.014	**1.079**	-0.696	0.007	-0.056	-0.109	-0.539	0.048	-0.003	-0.015	-0.031	0.061	-0.023	-0.32
DM	-0.119	0.038	0.994	**-0.755**	0.010	-0.062	-0.042	-0.111	-0.002	-0.011	-0.019	-0.039	0.079	-0.026	-0.06
WFL	-0.113	-0.074	0.142	-0.141	**0.055**	-0.001	-0.009	0.162	-0.072	0.007	0.009	0.012	-0.039	-0.004	-0.06
LP	-0.297	0.059	-0.296	0.229	-0.001	**0.205**	0.065	0.446	0.027	0.003	-0.012	-0.026	0.046	0.007	0.45**
NSP	-0.233	0.001	-0.415	0.113	-0.002	0.047	**0.283**	0.934	-0.112	-0.029	0.004	0.003	-0.016	-0.023	0.55**
NGP	-0.365	-0.002	-0.395	0.057	0.006	0.062	0.180	**1.471**	-0.111	-0.023	-0.006	-0.012	0.024	0.001	0.88**
HSW	-0.028	0.008	0.19	0.004	-0.014	0.02	-0.116	-0.595	**0.274**	0.039	-0.011	-0.013	0.037	0.03	-0.17
FLA	0.096	0.037	-0.061	0.140	0.007	0.010	-0.143	-0.596	0.183	**0.059**	0.013	0.022	-0.051	0.049	-0.23
CHL a	-0.145	0.197	0.17	-0.146	-0.005	0.026	-0.013	0.099	0.033	-0.008	**-0.098**	-0.126	0.36	-0.034	0.31
CHL b	-0.158	0.192	0.25	-0.221	-0.005	0.040	-0.008	0.139	0.027	-0.009	-0.091	**-0.134**	0.353	-0.034	0.34
TCHL	-0.132	0.196	0.182	-0.164	-0.006	0.026	-0.013	0.100	0.028	-0.008	-0.097	-0.130	**0.363**	-0.034	0.31
CP (%)	0.015	-0.059	-0.338	0.270	-0.003	0.019	-0.088	0.034	0.111	0.038	0.044	0.061	-0.167	**0.075**	0.012

Characters details are given inTable 2.
Residual effect = 0.03566292.

TABLE 5

Direct and indirect effects of component characters on grain yield per plant practised as uncut

Characters	PH	TN	WFL	LP	NSP	NGP	HSW	FLA	CHL a	CHL b	TCHL	CP (%)	GY
PH	-0.407	0.112	-0.009	0.329	-0.010	0.791	-0.169	-0.053	0.461	0.731	-1.103	0.054	0.728**
TN	-0.108	0.421	-0.041	0.118	-0.012	0.237	-0.024	-0187	0.527	0.922	-1.420	0.067	0.499**
WFL	0.012	-0.055	0.316	0.131	0.000	-0.083	-0.121	-0.328	1.08	1.382	-2.539	0.097	-0.102
LP	-0.307	0.114	0.094	0.437	-0.015	0.568	-0.444	-0.184	0.708	1.327	-1.859	0.180	0.620**
NSP	-0.208	0.256	-0.004	0.314	-0.021	0.684	-0.088	-0.168	0.88	1.274	-2.161	-0.011	0.750**
NGP	-0.291	0.090	-0.023	0.224	-0.013	1.107	0.085	0.017	1.103	1.177	-2.403	-0.139	0.935**
HSW	-0.074	0.011	0.041	0.211	-0.002	-0.102	-0.921	-0.015	-0.722	-0.197	1.326	0.507	0.062
FLA	-0.043	0.156	0.206	0.160	-0.007	-0.038	-0.028	-0.504	0.621	1.027	-1.591	0.125	0.084
CHL a	-0.066	0.079	0.122	0.110	-0.006	0.435	0.237	-0.111	2.807	3.327	-6.411	-0.160	0.363
CHL b	-0.084	0.110	0.124	0.165	-0.007	0.370	0.051	-0.147	2.657	3.515	-6.227	-0.148	0.380*
TCHL	-0.069	0.093	0.125	0.126	-0.007	0.414	0.190	-0124	2.802	3.407	-6.424	-0.164	0.369*
CP (%)	-0.033	0.042	0.046	0.118	0.000	-0.230	-0.699	-0.094	-0.673	-0.779	1.578	0.668	-0.056

Character details are given in Table 2.
Residual effect=0.1514707.

of grains per panicle, 100-seed weight, leaf area, chlorophyll content and protein content (Table 5).

In case of plant height, it was observed that a strong negative direct effect of this character could be nullified by the indirect effect of other characters such as length of panicle and number of grains per panicle so that the correlation value between this character and yield was significantly positive. Significantly positive correlation between tiller number and yield seems obvious because the direct effect of the character on yield was substantially positive and indirect effects of some of the characters like number of grains per panicle and chlorophyll content could also contribute towards such result. Interestingly, in spite of strong direct effect of weight of flag leaf on yield, no positive correlation could be discerned between these two characters. Similar observation could be recorded in case of the correlation between chlorophyll 'a' content and grain yield. In both these cases, a strong negative indirect effect of flag leaf area and total chlorophyll content could be observed. Length of panicle and number of grains per panicle exhibited strong to very strong direct effect on yield; also the indirect effect of the one character on the other might have consequently led to a significantly positive correlation. On the other hand, number of spikelets per panicle, in spite of exhibiting negative direct effect on yield the correlation was significantly positive. This might have been due to substantial indirect effect of tiller number, length of panicle, number of grains per panicle and chlorophyll 'a' and 'b' content. 100-grain weight, however, could not produce any correlation with grain yield, which might be due to resultant negative direct effect and positive indirect effect of length of panicle and chlorophyll content mainly. The highest direct effect was observed in case of chlorophyll 'b' content and consequently it produced significantly positive correlation with yield. Crude protein percentage, however, produced no correlation with grain yield though it had high direct effect. It produced high indirect effect via 100-seed weight and chlorophyll 'a' and 'b' content.

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