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Full Research Article

Correlation and Path Analysis Studies for Growth and Yield Contributing Traits in Indian Mustard (*Brassica juncea* L.)

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Abstract

A study was undertaken at West Bengal, India with Indian mustard var. varuna, during winter season of 2010-11 and 2011-12 in a split-plot design with three levels of irrigation (main-plots) and four levels of sulphur (sub-plots) with three replications. Experimental results revealed that application of two irrigations at 30 and 60 DAS, along with 45 kg S ha^{-1} influenced growth attributes and seed yield significantly. Further increase in S level upto 60 kg ha^{-1} although gave higher seed yield but the difference was non-significant. Highest consumptive use of water was recorded with two irrigations (at 30 and 60 DAS) while it was increased slightly with increase in S levels from 0 to 60 kg ha^{-1}. Sulphur @ 45 kg ha^{-1} recorded highest water use efficiency at all irrigation levels. Irrigation (twice at 30 and 60 DAS) fetched higher net return over single irrigation. At all irrigation levels, 45 kg S ha^{-1} recorded the highest net return and B:C ratio. Seed yield showed positive significant correlation with all the independent variables and CGR revealed the highest degree of correlation followed by RGR, NAR, plant height and number of primary branches plant^{-1}. It is obvious from path analysis that RGR had highest direct and positive effect on seed yield followed by CGR and number of primary branches plant^{-1}. Thus CGR, RGR and NAR were under genotypic control and this positive correlation toward seed yield would be favourable to breeder for genetic improvement of Indian mustard.

1. Introduction

Indian mustard (*Brassica juncea* L.) is an important edible oilseed crop in India that belongs to the family cruciferae. India is the third largest producer of rapeseed and mustard (6.41 mt) after China and Canada (Economic Survey, Statistical Appendix, 2013). In West Bengal, production of mustard during 2010-11 was 0.42 mt (sharing 5.1% of total production in the country) from 0.41 mha area, while the productivity (1.02 t ha^{-1}) was below to the national average of 1.19 t ha^{-1} (Economic review, GoWB 2012). In this region, mustard is grown after withdrawal of monsoon either as rainfed crop on residual soil moisture or as an irrigated crop. Most of the studies on irrigation requirements of *brassicas* are based on depletion of available soil moisture (DASM), critical growth stages and climatological approaches. Among the *brassicas*, Indian mustard is most responsive to irrigation. Two irrigations at pre-bloom (30 DAS) and pod development stages (60 DAS) are beneficial. An average increase of 62.9% and 41.7% in seed yield of mustard was obtained when the crop was irrigated twice at flowering and pod development stages and once at flowering stage, respectively (Panda et al., 2004). Sulphur plays an inevitable and imperative role in the formation of amino acids (methionine 21% and cysteine 27%), synthesis of protein, chlorophyll and oil content in oilseed crops. Increased sulphur levels have positive effect on leaf area index (Kumar and Yadav, 2007), dry matter per plant (Khanpara et al., 1993a) and other growth attributes of mustard. The adequate supply of sulphur increases mustard yield (Kumar et al., 2011) appreciably. The study, therefore, seeks the possible role of S in improving grain yield of mustard under normal and limited water supply.

Seed yield, a complex dependent character is contributed by several component characters. Direct selection for seed yield is often not very effective and thus indirect selection of some associated component traits may be useful (Hassan et al., 2013). Phenotypic correlations of yield with growth attributes and path analysis become useful for crop improvement programmes to select the desirable types (Ahmed and Kamaluddin, 2013). However, meagre information is available on these aspects in mustard for new alluvial zone of West Bengal. Keeping in view, a study was conducted to evaluate the performance and association among growth attributes and yield contributing traits of Indian mustard var. varuna under sub-tropical conditions.

2. Materials and Methods

Field experiments were conducted with Indian mustard variety 'Varuna' at Jaguli Instructional Farm under Bidhan Chandra Krishi Viswavidyalaya, West Bengal (latitude 22^{0}56' N, longitude 88^{0}32' E, altitude 9.75 m above MSL), India during winter season of 2010-11 and 2011-12. The soil was sandy loam in texture having 393.54 kg ha^{-1} available N, 52.6 kg ha^{-1} available P_2O_5, 154 kg ha^{-1} available K_2O, 14.3 mg kg^{-1} available S, 0.43% organic carbon and pH 6.21. Bulk density for the different layers of the soil were determined to be 1.24, 1.36, 1.38 and 1.41 g cc^{-1} for 0-15, 15-30, 30-45 and 45-60 cm, respectively. The twelve treatment combinations consisting of three irrigation treatments (I_1: single irrigation at 30 DAS; I_2: single irrigation at 60 DAS; I_3: irrigation twice at 30 and 60 DAS) as main plots and four sulphur doses (S_0:0; S_1:30; S_2:45; S_3:60 kg ha^{-1}) as sub plots, were laid out in a split-plot design with three replications. Elemental sulphur (Bentonite clay) was used as a source of S and applied at the time of land preparation, i.e. 30 days before sowing. The sub-plot size was 5×3 m^2. A general dose of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O kg ha^{-1} was applied through urea, DAP and MOP, respectively. Half dose of N and full dose of P_2O_5 and K_2O were applied as basal and rest half N was top-dressed at 30 DAS. Seeds were sown @ 7 kg ha^{-1} with a spacing of 45×10 cm^2 on third October during both the years of experimentation. Observations on various parameters were recorded at 40 DAS, 75 DAS and at harvest for plant height and dry matter accumulation (DMA) in plant shoot; at 40 and 75 DAS for leaf area index (LAI); at 40-75 DAS and 75 DAS-harvest for crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) and at harvest for number of primary branches plant^{-1} and seed yield. Different growth parameters were calculated as per the formula given below:

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf Area (cm}^2)}{\text{Land Area (cm}^2)}$$

$$\text{Crop Growth Rate (CGR)} = \frac{(W_2-W_1)}{(T_2-T_1)}$$, expressed as g m^{-2} day^{-1}.

$$\text{Relative Growth Rate (RGR)} = \frac{(\log_e W_2-\log_e W_1)}{(T_2-T_1)}$$, expressed as mg g^{-1} day^{-1}.

Where, W_1 and W_2 are dry weight of plant in g at times T_1 and T_2.

$$\text{Net Assimilation Rate (NAR)} = \frac{(W_2-W_1)\times(\log_e L_2-\log_e L_1)}{(T_2-T_1)\times(L_2-L_1)}$$, expressed as mg m^{-2} day^{-1}.

Where, L_1 and L_2 are total leaf area of plant at times T_1 and T_2.

Depth of irrigation water applied at 30 and 60 DAS was 40 and 50 mm, respectively. Consumptive use of water was calculated from the following relationship (Patel et al., 2008):

Consumptive use (mm)=Profile soil moisture use (mm)+effective rainfall (mm)+groundwater contribution (mm).

Groundwater contribution was considered nil as the depth of water table was more than 30 m below the surface throughout the period of experimentation.

$$CU = \sum_{i=1}^{n} \frac{M1i-M2i}{100} \times BDi \times Di \times ER$$

Where,

CU=consumptive use of water (cm); n=Number of soil layers sampled in the root zone depth D; M1i=Soil moisture percentage at the time of first sampling or after irrigation in the ith layer; M2i=Soil moisture percentage at the time of second sampling or before irrigation in the ith layer; BDi=Bulk density of soil in ith layer (g cc^{-1}); Di=Depth of ith layer of soil (cm) ER=Effective rainfall (cm).

Water use efficiency (kg ha^{-1} mm^{-1}) was determined by taking seasonal consumptive values of different treatments and yield of that treatment using the following formula:

$$\text{Water use efficiency (WUE)} = \frac{\text{Yield (kg ha}^{-1})}{\text{CU (mm)}}$$

Economic analysis was done on the basis of prevailing market prices of different inputs and outputs.

Correlation coefficient was estimated as per Al-Jibouri et al. (1958). The observed data was subjected to path analysis by using pooled correlation matrix as suggested by Dewey and Lu (1959).

3. Results and Discussion

3.1. *Effect of irrigation on growth and yield*

Application of two irrigations at 30 and 60 DAS resulted in favourable influence on vegetative growth at all dates of observation, which ultimately increased seed yield (Table 1). However, two irrigations were at par with single irrigation applied at 30 DAS in respect of plant height and LAI at 40 DAS; dry matter accumulation at 40 and 75 DAS and CGR at 40-75 DAS. But there was no significant difference between single irrigation for plant height and dry matter accumulation at 75 DAS and at harvest; for LAI at 75 DAS; for CGR and NAR at 40-75 and 75 DAS-harvest and also for primary branches plant^{-1}. In case of seed yield, single irrigation at 30 DAS was significantly superior to irrigation at 60 DAS. Water requirement of mustard (equivalent to consumptive use of water) varies from 200-300 mm (Singh and Sadhu, 1981). The present study revealed that two irrigations at 30 and 60 DAS were sufficient to get higher yield and the yield advantage was 8.33 and 13.46% over single irrigation at 30 and 60 DAS, respectively. Similarly, Saran and Prasad (2002) reported that in mustard normally two irrigations are given, first at the rosette stage (20-30 DAS) and second at the siliqua formation stage (50-60 DAS). According to Piri et al. (2012) the increase in yield may be attributed to better growth attributes namely plant height (Singh and Shrivastava, 1986), DMA (Panda et al., 2004), LAI (Prasad and Ehsanullah, 1990), number of primary branches plant^{-1} (Ghosh et al., 1994).

3.2. Effect of sulphur on growth and yield

Application of sulphur @ 60 kg S ha^{-1} had significant beneficial effect on various growth parameters which resulted increased seed yield (Table 1). This treatment was at par with 45 kg S ha^{-1} for plant height at 75 DAS and at harvest; for LAI at 40 DAS and also for seed yield. But there were no significant difference among 30, 45 and 60 kg S ha^{-1} in increasing the LAI at 75 DAS, DMA at 40 and 75 DAS, CGR at 40-75 and 75 DAS-harvest and number of primary branches plant^{-1}. In the present study irrespective of irrigation levels, yield of mustard var. varuna was also increased with the increasing rate of S from 0 to 60 kg ha^{-1}. Higher yield was obtained with 60 kg S ha^{-1} resulting in 17.94% increase over control (without S). Mohiuddin et al. (2011) also demonstrated 29.31% increase in mustard (var. SAU Sharisha-1) yield with 24 kg S ha^{-1} over zero-S. Results of experiments of different states in India indicate increase in seed yield of mustard due to sulphur fertilization to the tune of 12-13% under irrigated conditions (Tripathi and Sharma, 1993). Sulphur supposed to greatly influence growth attributes, mainly LAI (Kumar and Yadav, 2007) and DMA (Khanpara et al., 1993b). Mustard crop with higher plant height (Kashved et al., 2010), CGR (Kumar and Kumar, 2008), NAR (Piri and Sharma, 2006), primary branches plant^{-1} (Piri et al., 2011) produces more seed yield of mustard (Chand and Goutam, 2009) as compared to the crop grown without S.

3.3. Effect of irrigation and sulphur levels on water use efficiency and economics

Consumptive use of water increased with increase in irrigation levels (Table 2). However, highest consumptive use of water was recorded in case of two irrigations (at 30 and 60 DAS) followed by single irrigation either at 30 or 60 DAS. Consumptive use of water increased slightly with increase in the levels of sulphur from control to 60 kg S ha^{-1}. Application

Table 1: Variability parameters for seed yield and related traits of Indian mustard (Pooled data of 2 years)

Treatment	Plant height (cm)			Dry matter accumulation (g m^{-2})			Leaf area Index		Crop growth rate (g m^{-2} day^{-1})		Relative growth rate (mg g^{-1} day^{-1})		NAR (mg m^{-2} day^{-1})		NPB	Seed yield (t ha^{-1})
	40 DAS	75 DAS	Har-vest	40 DAS	75 DAS	Har-vest	40 DAS	75 DAS	40-75 DAS	75-Har-vest	40-75 DAS	75-Har-vest	40-75 DAS	75-Har-vest		
Irrigation levels																
At 30 DAS	45.12	105.55	142.71	207.79	378.93	417.04	0.86	1.84	4.89	1.16	21.28	8.60	3.53	2.41	7.55	1.43
At 60 DAS	42.39	104.38	140.34	186.39	373.77	413.55	0.75	1.77	4.33	1.12	20.53	7.49	3.45	2.37	6.92	1.35
At 30+ 60 DAS	46.27	117.15	149.71	206.26	382.84	431.43	0.87	2.08	5.13	1.28	21.76	10.69	3.84	3.01	7.69	1.56
SEm±	0.38	2.04	1.30	4.30	1.60	3.40	0.02	0.06	0.15	0.03	0.12	0.16	0.05	0.12	0.15	0.02
CD (p=0.05)	1.49	8.01	4.10	13.87	5.26	11.07	0.07	0.23	0.61	0.11	0.38	0.51	0.18	0.46	0.51	0.07
Sulphur (kg ha^{-1})																
0	41.20	100.27	138.35	188.36	366.43	406.76	0.70	1.73	4.18	1.08	19.92	7.99	3.19	2.25	6.93	1.28
30	43.39	106.26	143.91	200.06	378.34	418.11	0.82	1.86	4.74	1.15	20.85	8.41	3.42	2.26	7.34	1.42
45	45.20	115.39	146.12	204.59	383.22	423.70	0.88	1.99	5.09	1.23	21.81	9.26	3.67	2.83	7.64	1.54
60	48.57	114.17	148.64	207.59	386.06	437.21	0.91	2.01	5.13	1.29	22.17	10.05	4.15	3.04	7.63	1.56
SEm±	0.65	2.31	1.35	3.67	3.67	3.35	0.03	0.07	0.23	0.05	0.11	0.18	0.11	0.13	0.13	0.03
CD (p=0.05)	1.93	6.87	4.21	10.01	10.90	9.95	0.08	0.20	0.67	0.15	0.34	0.54	0.34	0.37	0.38	0.08

DAS: Days after sowing; NAR: Net assimilation rate; NPB: No. of primary branches plant^{-1}

of 45 kg S ha^{-1} recorded highest water use efficiency in case of single irrigation (30 DAS) and double irrigation (30 and 60 DAS) but in case of single irrigation (60 DAS), application of 60 kg S ha^{-1} recorded highest water use efficiency.

A perusal of the data presented in table 2 revealed that application of double irrigation to mustard fetched higher net return and B:C ratio over single irrigation either at 30 or 60 DAS mainly due to higher seed yield. Irrespective of irrigation levels, mustard that received 45 kg S ha^{-1} recorded the highest net return and B:C ratio followed by 60 kg S ha^{-1}. As only 3% increase in seed yield was observed under double irrigation (both at 30 and 60 DAS) over single irrigation with same level of S (45 kg ha^{-1}), the treatment (i.e. single irrigation at 30 DAS with 45 kg S ha^{-1}) yielded more B:C ratio simply because of the fact that the total cost incurred was more in the former one whereas net return was not very high (only 2.66% than later one).

3.4. Association among growth parameters and seed yield

From the experimental results, actual and linear association between seed yield and dry matter accumulation (DMA) or LAI or plant height or CGR can be ascribed (Figure 1). In case of DMA and seed yield, the value of intercept term is 0.077 and that of the parameter estimate is 0.003 in the regression equation. The square of multiple correlation coefficient or coefficient of determination (R^2) is 0.333. There are two extreme values one in the upper side and another in the lower side of the curve which signifies the partial significance of the correlation of the two parameters. Similarly, in case of LAI and seed yield and also in case of plant height and seed yield, R^2 are 0.266 and 0.536, respectively which signifies partial significance of their correlation. In case of CGR and seed yield, the curve is well fitted and this indicates the high significance of the correlation of these two parameters. Here the R^2 value is 0.779 and thus it can be said that 77.9% of the variation in the yield (dependent variable) has been explained by variation in the CGR (independent variable). Significant correlations have been observed between most of the growth and yield characteristics in the present study. Correlation studies suggest that CGR, RGR and NAR could be important selection criteria for higher yield of Indian mustard var. varuna.

3.5. Relationship among independent and dependent variables

Correlation matrix of all the variables exhibits the significant relationship among the variables (Table 2). Seed yield as dependent variable showed the positive significant correlation with all the independent variables among which CGR revealed the highest degree of correlation followed by RGR, NAR, plant height and number of primary branches $plant^{-1}$. All the above mentioned variables were significant at 1% level of significance with seed yield. This indicated that CGR, RGR and NAR were strongly associated with seed yield. Rest two variables viz. LAI and DMA were also positively significant with seed yield. The matrix also points out the different degrees of significant correlation coefficients among the independent variables. The correlation of independent variables among themselves revealed that plant height and DMA, LAI and DMA, plant height and CGR, CGR and DMA, plant height and RGR, RGR and DMA, LAI and RGR, CGR and RGR, CGR and NAR, RGR and NAR, plant height and number of primary branches $plant^{-1}$ had very high, positive and significant correlation among themselves. On the other hand, plant height and LAI, plant height and NAR, LAI and CGR, LAI and NAR, LAI and number of primary branches $plant^{-1}$, DMA and NAR, DMA and number of primary branches $plant^{-1}$, CGR and number of primary branches $plant^{-1}$, RGR and number of primary branches $plant^{-1}$, NAR and number of primary branches $plant^{-1}$ had very low correlation among themselves. It is obvious from the data (Table 3) that RGR had highest direct and positive effect on seed yield followed by CGR and number of primary branches $plant^{-1}$. Perusal of indirect effects of RGR revealed that it also had a high indirect effect via CGR and number of primary branches $plant^{-1}$. Similarly, direct effect of CGR on seed yield was due to highest indirect effect of RGR followed by number of primary branches $plant^{-1}$. So, all the parameters were positively correlated with seed yield whereas path analysis expresses the negative direct effects of plant height, DMA, LAI and NAR. Although those four parameters had negative direct effect on seed yield their correlation with

Table 2: Water use efficiency and economics of Indian mustard under different treatment combinations

Treatment combina-tions	Consump-tive use (mm)	Water use efficiency (kg ha^{-1} mm^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
I_1S_0	157.59	8.00	56700	34426	2.55
I_1S_1	157.73	8.69	61650	37743	2.58
I_1S_2	162.95	9.51	69750	45026	2.82
I_1S_3	166.17	9.27	69300	43760	2.71
I_2S_0	158.84	7.05	50400	28126	2.26
I_2S_1	152.25	8.87	60750	36843	2.54
I_2S_2	156.44	9.27	65250	40526	2.64
I_2S_3	157.39	9.47	67050	41510	2.63
I_3S_0	192.32	7.54	65250	41476	2.74
I_3S_1	195.59	7.87	69300	43893	2.73
I_3S_2	197.42	8.16	72450	46226	2.76
I_3S_3	202.48	8.15	74250	47210	2.75

I_1: 1 irrigation at 30 DAS; I_2: 1 irrigation at 60 DAS; I_3: 2 irrigations at 30 & 60 DAS; S_0: No sulphur; S_1: 30 kg S ha^{-1}; S_2: 45 kg S ha^{-1}; S_3: 60 kg S ha^{-1}

Table 3: Phenotypic correlation matrix for yield and related traits in Indian mustard (Pooled data of 2 years)

Parameters	Plant height	LAI	DMA	CGR	RGR	NAR	Number of primary branches plant^{-1}	Seed yield
Plant height	1							
LAI	0.669*	1						
DMA	0.908**	0.81**	1					
CGR	0.848**	0.675*	0.77**	1				
RGR	0.906**	0.774**	0.882**	0.892**	1			
NAR	0.701*	0.608*	0.68*	0.923**	0.812**	1		
Number of primary branches plant^{-1}	0.845**	0.437*	0.6*	0.705*	0.703*	0.575*	1	
Seed yield	0.732**	0.516*	0.577*	0.883**	0.856**	0.818**	0.715**	1

*, **Significant at the 0.05 and 0.01 probability levels, respectively

Table 4: Estimates of direct and indirect effects on seed yield and related traits (Pooled data of 2 years)

Parameters	Plant height	LAI	DMA	CGR	RGR	NAR	Number of primary branches plant^{-1}	Total correlation with seed yield
Plant height	*-0.883*	-0.173	-0.146	0.671	1.080	-0.160	0.343	0.732
LAI	-0.591	*-0.258*	-0.131	0.534	0.923	-0.139	0.178	0.516
DMA	-0.802	-0.209	*-0.161*	0.609	1.052	-0.155	0.244	0.577
CGR	-0.749	-0.174	-0.124	*0.791*	1.063	-0.210	0.286	0.883
RGR	-0.800	-0.200	-0.142	0.705	*1.192*	-0.185	0.286	0.856
NAR	-0.619	-0.157	-0.110	0.730	0.968	*-0.228*	0.234	0.818
Number of primary branches plant^{-1}	-0.746	-0.113	-0.097	0.558	0.838	-0.131	*0.406*	0.715

Residual effect: 0.050; Italics figures represent direct effects and others indirect effects

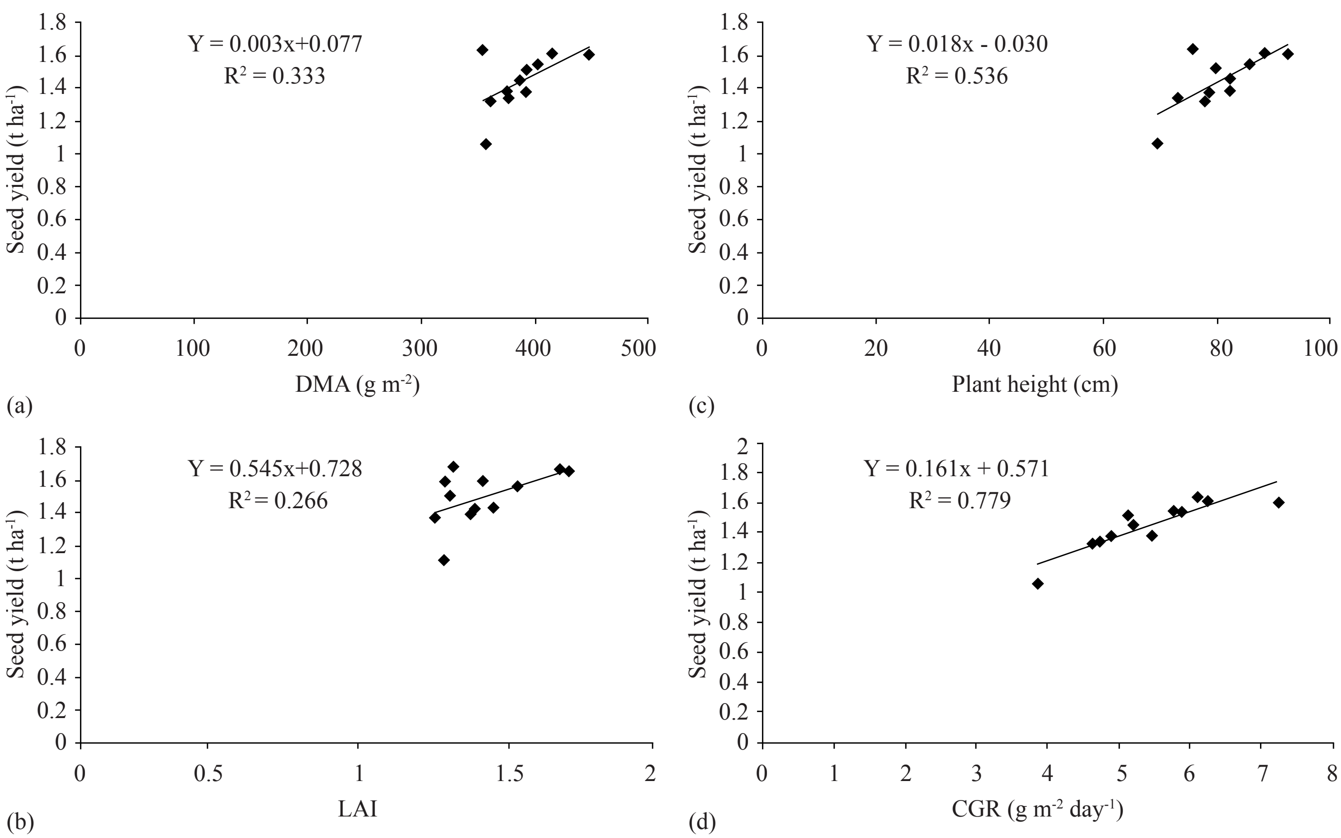

Figure 1: Correlation coefficients of seed yield with (a) DMA, (b) LAI, (c) plant height and (d) CGR of Indian mustard

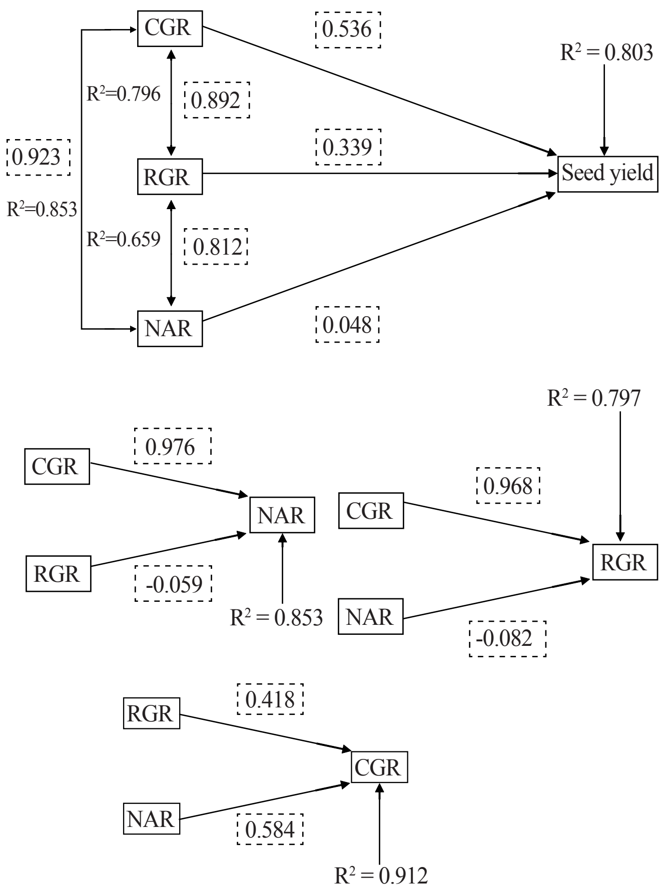

Figure 2: Phenotypic path diagram for grain yield and related traits in Indian mustard var. varuna (values in the dotted boxes represent standardized β coefficients of the respective linear regressions)

seed yield was through positive indirect effect of CGR and RGR (Figure 2). Three growth parameters viz. CGR, RGR and NAR had high correlation with seed yield via negative indirect effect of plant height, DMA, LAI and NAR. Standard equation of regression was:

$$Y=-0.883X_1-0.258X_2-0.161X_3+0.791X_4+1.192X_5-0.228X_6+0.406X_7 \quad (1)$$

Here in this equation, Y is the seed yield and X_1, X_2, X_3, X_4, X_5, X_6 and X_7 are plant height, LAI, DMA, CGR, RGR, NAR and number of primary branches plant^{-1}, respectively. Though the seed yield showed different correlation coefficients with each of the independent variables, however, simple correlation should not be interpreted as having causal relationship between two variables (Gomez and Gomez, 1984). Correlation study measures the mutual association without definite cause. So correlation study may not always provide a true picture of the association. The association become complex when many correlated characters are affecting a particular variable. Hence, a path coefficient analysis enables us to evaluate the direct effect of one cause on an effect and its indirect effect through other causes (Kumar et al., 2013). Misra et al. (2013) also opined that path coefficient is simply a standardized partial regression coefficient and hence permits us to identify direct and indirect effects of different characters on seed yield. Path analysis in the present study revealed that the correlation of plant height, DMA, LAI and number of primary branches plant^{-1} with seed yield was through positive indirect effect of CGR and RGR, and negative indirect effect of NAR. High correlation of NAR with seed yield was due to positive indirect effect of CGR, RGR and number of primary branches plant^{-1} and negative indirect effect of plant height, DMA, LAI. Thus it can be inferred that CGR, RGR and NAR all these three parameters were under genotypic control. High direct effect of a character on yield indicates that it was controlled by additive type of gene action (Khan et al., 2000).

4. Conclusion

Two irrigations at 30 and 60 DAS plus 45 kg S ha^{-1} showed higher yield components, yield and CU of water. Sulphur @ 45 kg ha^{-1} recorded higher WUE at all irrigation levels. Mustard receiving 45 kg S ha^{-1} recorded higher WUE, net return and B:C ratio. Both CGR and RGR had highest direct effect on yield. Hence, plant breeders can use CGR and RGR as selection indices for phenotypic improvement in yield of Indian mustard.

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