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Path analysis studies of EMS-mutagenized mutant population of hexaploid wheat (*Triticum aestivum* L.)

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Abstract
Mutated genetic resources play a crucial role and are of utmost importance in gene/allele characterization. Currently, hexaploid wheat mutated resources are rarely available. In the present investigation, a mutated population comprising 1,536 EMS-induced mutation lines (M7 generation) of bread wheat (*Triticum aestivum* L.) were used as an experimental material. Mutant population was developed and maintained at G.B.P.U.A.T, Pantnagar. The experiment was conducted in augmented block design II. in season 2019-20 at Norman E. Borlaug Crop Research Centre G.B.P.U.A.T, Pantnagar. The study revealed that number of tillers per plant recorded significantly higher direct effect on grain yield per plant followed by number of grains per spike, thousand grain weight, plant height, ear length, flag leaf width, grain length, flag leaf area and number of spikelet per spike. The association between grain yield per plant and these characters was significant. The direct negative effects on grain yield was observed by grain width, flag leaf length and peduncle length.

Keywords: Path analysis, wheat, mutagenesis, EMS

Introduction

Cereals play a crucial role to meet with the ever increasing global food demand of growing population, predominantly in developing countries where cereal-based crop production is the chief source of nutrition and calorie intake (Nikos and Jelle, 2012; Shiferaw, 2013) [10, 17]. Wheat is a widely adapted crop, it is grown in diversified environments from temperate irrigated to dry and high rainfall areas and from warm humid to dry cold environments (Zarea-fizabady and Ghodsi, 2004; Falconer and Mackay, 1996) [5, 22]. Wheat occupies around 217 million hectares with an annual production of around 731 million tonnes (USDA, 2018) [7]. Wheat is the major cereal crop in the regions of North Africa and west and central Asia. As India is enriched with a diverse agro ecological conditions, it ensures food and nutrition security to the Indian population. The wheat production in India has been increased significantly from 75.81 million tonnes in 2006-2007 to an all-time record high 99.70 million tonnes in year 2019 About 29.58 million hectares are grown to wheat in India. In 2019-2020 cropping season the total production reached 99.70 million tonnes thus making India the second largest wheat producer in the world (Sharma *et al*; 2015, Sharma and Sendhil, 2016) [15, 16]. Major wheat growing states in India are Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Bihar, Rajasthan, and Gujarat. Demand of India's wheat has been increased tremendously The country has exported 2,17,354.22 million tonnes of wheat to the world in year 2019-20 that contributes to the worth of Rs. 439.16 crores/61.84 USD Millions. The major destinations of export are Nepal, Bangladesh, U Arab Emts, Somalia and Korea (APEDA). In cereals, grain yield is a very complex phenomenon and involves multi growth factors. Thus, it is considered, selection on the basis of traits with high heritability makes the progress easier. Simple correlation analysis indicates the degree of association between traits but it cannot provide the reasons behind this association. Therefore, simple correlation alone are not effective in revealing the relationship among traits and thus, researchers emphasized in the need for a component analysis in which correlation of each yield component with yield and with each other is determined (Hardwick and Andrews, 1980) [6]. Therefore, the exact contribution of each component can be analyzed.

A path co-efficient is a standardized partial regression coefficient and measures the direct influence of one trait upon another. Path co-efficient analysis permits the separation of a correlation coefficient into two components i.e. direct and indirect effects (Dewey and Lu 1959) [4].

Material and Methods

The wheat cultivar DPW-621-50 was used to generate a mutant population. Seeds of DPW-621-50 were soaked in 0.7% (v/v) EMS solution (Sigma-Aldrich®) and kept at 75 rpm on a shaker overnight at room temperature (Dong *et al.*, 2009[4]; Uauy *et al*., 2009) [4, 13]. After EMS treatment, the seeds were thoroughly washed under running tap water for 6 h and then sown in the field at Norman E. Borlaug Crop Research Centre G.B.P.U.A.T, Pantnagar. Fertilizers and irrigations were applied as per recommended package of practice. One spike from each M1 plant was harvested. Single seed from each M1 plant were grown to maturity and phenotyped (Uauy *et al.,* 2009) [13] for morphological and yield related traits such as plant height, number of tillers, number of spikelets per spike, number of grains per spike, thousand grain weight and grain yield per plant. Initial screening of mutants for different traits was performed on the basis of phenotyping. Selection of the best lines from M_4 to M_7 was carried out based on the yield of individual plants. The 1536 mutant lines of M_6 generations together with the parent cv. DPW 621-50 and with 4 checks *viz.* HD 2967, HD 3086, UP 2628 and WH 1105, were planted in augmented block design in a field trial for further evaluation. Each line was grown in 2 m long, 30 cm between rows, and 10 seeds planted per row. The data on morphological and agronomical traits such as number of tillers per plant, plant height, flag leaf (length), flag leaf (width), flag leaf area, ear length, peduncle length, number of spikelet per spike, number of grains per spike, grain length, grain width, thousand grain weight and grain yield per plant, were recorded. Afterward the path coefficient analysis was carried out according to Dewey and Lu (1959) [3]. The grain yield per plant was kept as the resultant variable while other characters as casual factors.

Results

The path coefficient analysis as suggested by Dewey and Lu (1959) [3] was applied to reveal direct and indirect contribution of each character to grain yield. The present study was taken up in an attempt to assess direct and indirect effects of different characters on grain yield among 1540 genotypes (including 1,536 mutant lines and 4 checks) of wheat. Direct and indirect effects are presented in Table-1. Direct and indirect effect of all 12 characters on grain yield per plant are given as follows:

Table 1: Path analysis of grain yield per plant and its attributing characters

Character	Correlation with GYP	Direct effects	Indirect effects via											
			NT	PH	FLL	FLW	FLA	EL	PL	NSS	NGS	GL	GW	TGW
NT	0.703**	0.599	0.599	0.132	0.090	0.059	0.120	0.084	0.026	0.072	0.089	0.055	0.069	0.025
PH	0.405**	0.063	0.014	0.063	-0.002	0.017	0.014	0.036	0.028	0.017	0.021	0.008	0.013	0.007
FLL	0.074**	-0.024	-0.004	0.001	-0.024	0.000	-0.012	-0.001	-0.002	0.001	0.001	-0.001	0.001	-0.003
FLW	0.200**	0.017	0.002	0.004	0.000	0.017	0.009	0.005	0.002	0.002	0.003	0.001	0.002	0.001
FLA	0.225**	0.009	0.002	0.002	0.005	0.005	0.009	0.002	0.001	0.001	0.001	0.001	0.001	0.001
EL	0.339**	0.026	0.004	0.015	0.001	0.008	0.006	0.026	0.005	0.008	0.009	0.004	0.005	0.003
PL	0.144**	-0.019	-0.001	-0.008	-0.002	-0.002	-0.003	-0.004	-0.019	-0.002	-0.002	-0.001	-0.001	-0.003
NSS	0.478**	0.003	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.003	0.002	0.001	0.001	0.001
NGS	0.697**	0.53	0.079	0.177	-0.018	0.083	0.059	0.172	0.069	0.342	0.530	0.180	0.190	0.125
GL	0.346**	0.011	0.001	0.001	0.000	0.001	0.001	0.002	0.000	0.003	0.004	0.011	0.007	0.005
GW	0.352**	-0.023	-0.003	-0.005	0.001	-0.003	-0.002	-0.004	-0.001	-0.006	-0.008	-0.014	-0.023	-0.010
TGW	0.357**	0.205	0.009	0.022	0.022	0.016	0.024	0.021	0.033	0.037	0.048	0.100	0.088	0.205

Note: NT= Number of tillers, PH= Plant height, FLL= Flag leaf length, FLW= Flag length width, FAA= Flag leaf area, EL= Ear length, PL= Peduncle length, NSS= No. of spikelet per spike, NGS= No. of grains per spike, GL= Grain length, GW=, TGW= Thousand grain weight and GYP= Grain yield per plant

*, ** Indicates significant at 5% and 1% level of significance.

Direct Effect

Among the 13 characters studied number of tillers per plant (0.599) recorded significantly higher direct effect on grain yield per plant followed by number of grains per spike (0.530), thousand grain weight (0.205), plant height (0.063), ear length (0.026), flag leaf width (0.017), grain length (0.011), flag leaf area (0.009) and number of spikelet per spike (0.003). The association between grain yield per plant and all these characters was significant and positive.

Grain width (- 0.023), flag leaf length (- 0.024) and peduncle length (- 0.019) was recorded significantly and association between grain yield and these characters was significant and negative.

Indirect effect

Number of tillers per plant showed indirect positive effect on plant height (0.132), flag leaf area (0.120), flag leaf length (0.090), number of grains per spike (0.089), ear length (0.084), number of spikelet per spike (0.072), grain width (0.069), flag leaf width (0.059), grain length (0.055), peduncle length (0.026) and thousand grain weight (0.025).

Plant height showed indirect positive effect on ear length (0.036), peduncle length (0.028), number of grains per spike (0.021), number of spikelet per spike (0.017), flag leaf width (0.017), flag leaf area (0.014), number of tillers per plant (0.014), grain width (0.013), grain length (0.008) and thousand grain weight (0.007). Flag leaf length exhibited indirect positive effect on plant height (0.001), number of spikelet per spike (0.001), number of grains per spike (0.001) and grain width (0.001).

Flag leaf width exhibited indirect positive effect on flag leaf area (0.009), ear length (0.005), plant height (0.004), number of tillers per plant (0.002), peduncle length (0.002), number of spikelet per spike (0.002), grain width (0.002), thousand grain weight (0.001) and grain length (0.001).

Flag leaf area showed indirect positive effect on flag leaf length (0.005), flag leaf width (0.005), number of tillers per plant (0.002), plant height (0.002), ear length (0.002), peduncle length (0.001), number of spikelet per spike (0.001), number of grains per spike (0.001), grain length (0.001), grain width (0.001) and thousand grain weight (0.001).

Ear length showed indirect positive effect on plant height (0.015), number of grains per spike (0.009), flag leaf width (0.008), number of spikelet per spike (0.008), flag leaf area (0.006), grain width (0.005), peduncle length (0.005), grain length (0.004), thousand grain weight (0.003) and flag leaf length (0.001). Peduncle length exhibited indirect positive effect on none of the character.

Number of spikelet per spike showed indirect positive effect on number of grains per spike (0.002), ear length (0.001), plant height (0.001), grain length (0.001), grain width (0.001) and thousand grain weight (0.001).

Number of grains per spike exhibited indirect positive effect on number of spikelet per spike (0.342), grain width (0.190), grain length (0.180), plant height (0.177), ear length (0.172), thousand grain weight (0.125), flag leaf width (0.083), number of tillers (0.079), peduncle length (0.069) and flag leaf area (0.059). Grain length showed indirect positive effect on grain width (0.007), thousand grain weight (0.005), number of grains per spike (0.004), number of spikelet per spike (0.003), ear length (0.002), number of tillers per plant (0.001), plant height (0.001), flag leaf width (0.001) and flag leaf area (0.001). Grain width exhibited indirect positive effect on flag leaf length (0.001). Thousand grain weight showed indirect positive effect on grain length (0.100), grain width (0.088), number of grains per spike (0.048), number of spikelet per spike (0.037), peduncle length (0.033), flag leaf area (0.024), plant height (0.022), flag leaf length (0.022), ear length (0.021), flag leaf width (0.016) and number of tillers per plant (0.009). Selection of genotypes for grain yield is based on its components and their relation to each other. Path coefficient analysis splits the correlation coefficient into direct and indirect effects. Here in the present investigation path analysis was carried out to estimate the direction and magnitude of direct and indirect effects of various yield and yield contributing characters. If the correlation between a casual factor and direct effect is more or less of equal magnitude this indicates the perfect and true relationship between the different traits and direct selection through these will be worthwhile. However, if the correlation coefficient is positive and the direct effect is negative or negligible, this suggests that the indirect casual factors are to be considered in simultaneous selection. The characters number of tillers, number of grains per spike, thousand grain weight, plant height, ear length, flag leaf width, grain length, flag leaf area and number of spikelet per spike recorded high magnitude of direct effect accomplished by highly significant correlation in the desired direction with grain yield per plant indicating true and direct relationship between these characters, suggesting direct selection based on these characters would help in selecting the high yielding mutant lines of wheat, which could be utilized in further various breeding programmes. These results were in accordance with the earlier findings of Çifci (2012) [2], Kamboj (2010) [8] and Nukasani *et al*. (2013) [11].

Conclusion

Path analysis revealed that number of tillers per plant exhibited high positive direct effect on grain yield per plant followed by number of grains per spike, thousand grain weight, plant height, ear length, flag leaf width, grain length, flag leaf area and number of spikelet per spike. The association between grain yield and these characters was significant. The direct negative effects on grain yield observed by Grain width, flag leaf length and peduncle length. Mutant lines used in breeding programme for the above characters exhibiting positive direct and indirect effects with correlation.

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