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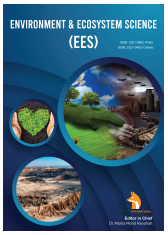

RESEARCH ARTICLE

CORRELATION AND PATH COEFFICIENT ANALYSIS OF ELITE SPRING WHEAT LINES DEVELOPED FOR HIGH TEMPERATURE TOLERANCE

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ABSTRACT

A set of fifty bread wheat genotypes that comprised of 49 high temperature tolerant lines from CIMMYT and a local check Gautam were evaluated with an objective to study the character association between yield and yield related components at the research farm of Agriculture and Forestry University, Rampur during the wheat season 2016/2017 under late sown condition. The experiment was laid out following Alpha Lattice design with two replications. Grain yield has positive and significant correlations with biomass yield, harvest index, thousand kernel weight, plant height, Soil Plant Analyzer Development ($SPAD_1$) flag leaf area, $SPAD_2$ and number of grain per spike. Negative and significant correlations were observed between grain yield with days to flowering, days to heading and days to booting. Path analysis revealed that biomass weight has maximum positive direct effect on grain yield followed by harvest index, days to booting, days to flowering, $SPAD_3$, root angle of basket condition, number of root, number of grains per spike, and number of tiller per meter square. On the other hand, days to booting, flag leaf area, physiological maturity, $SPAD_1$, $SPAD_2$, root length, days to flag leaf senescence, plant height, canopy temperature depression and thousand kernel weight showed the negative direct effect on grain yield.

KEYWORDS

Character association, SPAD, Wheat etc.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is a cereal crop which belongs to family Poaceae. Worldwide, it is grown on nearly 218.5 million hectares, with a production of 771.7 million tons (FAOSTAT, 2017). It is a primary staple food crop for South Asia; it is grown on nearly 49.5 million hectares, with a production of 146.6 million tons (FAOSTAT, 2017). Annual production of wheat in Nepal is 1.94 million tons harvested from 0.706 million hectares with the average yield of 2.75 tons per hectare (MoALD, 2018). Yield of wheat in Nepal is far below than the most wheat producing countries and is still insufficient to fulfill the demands of growing population.

Grain yield is the outcome due to the actions and interactions of various traits : direct contributing traits such as, number of effective tiller in unit area , number of fertile panicle in unit area and 1000-grain weight and indirect contributing traits such as plant height, panicle length , seed length, seed setting rate etc (Huang et al., 2013). So, it is essential to understand the changes in yield, yield components and associated traits to improve the knowledge on yield-limiting factors and to aid on future breeding strategies (Royo et al., 2007). Generally, correlation analysis is carried out to determine the relationship between yield with its different component traits but correlation alone cannot present the true association of traits with yield due to inter-relationships between component traits themselves. Path coefficient is most powerful tools help to analyze nature, extent and direction of selection; it is used to establish the exact relationships in terms of cause and effect, identify the direct, indirect and total (direct plus indirect) causal effects. Correlation and path coefficient analysis help to improve selection efficiency in future breeding program based on trait selection (Kandel et al., 2017). Previous researchers have already quantified associations between yield and yield attributing traits in a number of studies (Zahid et al., 2006; Chandra et al., 2009; Huang et al., 2011). This study was carried out with the objective to find out the inter-relationship and direct and indirect effects of various yield attributing traits among themselves and with grain yield.

2. MATERIALS AND METHODS

Fifty bread wheat genotypes obtained from the Agriculture Botany Division NARC, Khumaltar, Nepal used for this study. The field experiment was conducted at the research farm of Agriculture and Forestry University, Rampur, Chitwan, Nepal, from December 2016 to April 2017. 50 wheat genotypes were evaluated in alpha lattic design with two replications. Individuals plot size was 3 m^2. Seed sown on 25 cm apart row with continuous sowing. Fertilizer was applied at the rate of 120:60: 40 NPK kg ha^{-1}. Data were taken on root traits and agro-morphological traits. Root system was assessed at Zadok's growth stage 12 (2 leaves unfolded). Five seedlings per plot were taken for assessing the root traits namely; root length and number of root. Seedling sample was taken carefully uprooting. Five seedlings per plot were randomly sampled by carefully uprooting which was facilitated by loosening of the soil below the plant with a spatula. As soon as the seedlings were collected, the root portion was cleaned in a running tap water to remove soil particles and other inert substances.

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The numbers of primary (main) roots were counted and the mean root number was determined. Root length was measured (cm) on the longest root form the root base (scutellum) to the tip. Agro-morphological traits such as days to 50 % booting, heading and flowering are taken from plot where 90 % plant of plant showing such character. Characters like flag leaf area, plant height, effective number of spike, Chlorophyll content, 1000 grain weight, biomass yield, grain yield, harvest index from 5 plants of individual plot. Chlorophyll content was measured at three different stages in ten days interval after heading from flag leaf of randomly selected five plants. Harvest index was calculated as the proportion of grain yield to the total biomass yield. Root angle was assessed at mid tillering stage following the Basket method described by and with some modifications (Atsushi et al., 1980; Hamada et al., 2012).

2.1 Statistical analysis

All collected data were entered into Microsoft Excel version.19 and Pearson's correlation analysis was performed using statistical software IBM SPSS 17 (Bryman and Cramer, 2012). Genotypic and phenotypic coefficient of correlation between two characters was determined by using variance and covariance components (Weber and Moorthy ,1952). Path coefficient analysis using the Microsoft Excel version 13 following the procedure (Dewey and Lu, 1959). The path coefficient simultaneous equations were adopted (Ahmed et al., 2002).

r1y = P1 + r12P1 + r13P3

Similarly for r2y and r3y

r2y = r21P1 + P2 + r23P3;

r3y= r31P1 + r32P2 + P3.

The residual effect was obtained as Px = 1 - Pxy rxy. Where, Px = residual effect of variable X;
Pxy rxy= product of direct effect of variance X and its correlation (r) with yield (Y).

Table 1: List of fifty wheat genotypes

S.N.	Name of genotypes	S.N.	Name of genotypes	S.N.	Name of genotypes
1	Gautam (Local check)	18	MXI15-16 M37ES24SA15H 66	35	MXI15-16 M37ES24SA15H 182
2	MXI15-16 MULTTESTIGOS 6	19	MXI15-16 M37ES24SA15H 67	36	MXI15-16 M37ES24SA15H 196
3	MXI15-16 MULTTESTIGOS 10	20	MXI15-16 M37ES24SA15H 77	37	MXI15-16 M37ES24SA15H 208
4	MXI15-16 MULTTESTIGOS 11	21	MXI15-16 M37ES24SA15H 78	38	MXI15-16 M37ES24SA15H 213
5	MXI15-16 MULTTESTIGOS 13	22	MXI15-16 M37ES24SA15H 82	39	MXI15-16 M37ES24SA15H 215
6	MXI15-16 M37ES24SA15H 5	23	MXI15-16 M37ES24SA15H 96	40	MXI15-16 M37ES24SA15H 218
7	MXI15-16 M37ES24SA15H 10	24	MXI15-16 M37ES24SA15H 113	41	MXI15-16 M37ES24SA15H 224
8	MXI15-16 M37ES24SA15H 18	25	MXI15-16 M37ES24SA15H 116	42	MXI15-16 M37ES24SA15H 226
9	MXI15-16 M37ES24SA15H 20	26	MXI15-16 M37ES24SA15H 118	43	MXI15-16 M37ES24SA15H 230
10	MXI15-16 M37ES24SA15H 25	27	MXI15-16 M37ES24SA15H 128	44	MXI15-16 M37ES24SA15H 233
11	MXI15-16 M37ES24SA15H 33	28	MXI15-16 M37ES24SA15H 135	45	MXI15-16 M37ES24SA15H 235
12	MXI15-16 M37ES24SA15H 35	29	MXI15-16 M37ES24SA15H 139	46	MXI15-16 M37ES24SA15H 236
13	MXI15-16 M37ES24SA15H 47	30	MXI15-16 M37ES24SA15H 140	47	MXI15-16 M37ES24SA15H 245
14	MXI15-16 M37ES24SA15H 50	31	MXI15-16 M37ES24SA15H 144	48	MXI15-16 M37ES24SA15H 248
15	MXI15-16 M37ES24SA15H 52	32	MXI15-16 M37ES24SA15H 153	49	MXI15-16 M37ES24SA15H 272
16	MXI15-16 M37ES24SA15H 55	33	MXI15-16 M37ES24SA15H 160	50	MXI15-16 M37ES24SA15H 275
17	MXI15-16 M37ES24SA15H 56	34	MXI15-16 M37ES24SA15H 162		

3. Results and Discussions

3.1 Correlation grain yield and other traits

Pearson's correlation analysis showed significant correlations between most of the studied variables (Table 2). Grain yield showed positive and significant correlations with biomass (0.53**), harvest index (0. 52**), thousand kernel weight (.47**), plant height (.40**), $SPAD_2$ (.37**), flag leaf area (.32**), $SPAD_1$ (.27**) and number of grain per spike (.26**). Similar findings were reported (Royo et al., 2007). Previous researchers also found the significant positive correlation between yield and flag leaf area (Ayeneh et al., 2002; Rahman et al., 2013). Previous researcher also reported the positive correlation of plant height with grain yield (Reza et al., 2014). Positive and significant association between thousand kernel weight and seed yield is in agreement with the finding (Prakash et al., 1990). Negative and significant correlations were observed between grain yield with days to flowering (-.40**), days to heading (-.39**) and days to booting (-.33**). In other study also reported the negative and significant correlation between days to heading and grain yield (Yağdı and Sözen, 2009). Positive and significant correlation was found between days to booting and days to heading (.92**), between days to booting and days to flowering (.89**), between days to heading and days to flowering (.95**), and between flag leaf senescence and physiological maturity (.639**).

Days to booting (-.23*) and days to heading (-.23*) was negatively correlated with $SPAD_1$. Similarly, flag leaf senescence (.34**) and physiological maturity (.42**) showed significant positive correlations with $SPAD_3$. Flag leaf area showed significant positive correlation with biomass yield (.40**), plant height (.34**) and $SPAD_1$ (.35**) while showed negative correlation with days to booting (-.37**) and days to heading (-.33**). Plant height showed significant positive correlation with biomass yield (.50**), $SPAD_1$ (.34**), $SPAD_2$ (.39**), $SPAD_3$ (.43**), number of grain per spike (.40**) and number of root (.25*). Harvest index showed significant positive correlations with days to booting (.30**), days to heading (.34**) and days to flowering (.35**) while showed negative correlation with tillers per m^2 (-.39**). Similarly, number of grain per spike (.50**) and tillers per m^2 (.47**) showed significant positive correlations with biomass yield. Thousand kernel weight showed significant negative correlations with number of grain per spike (-.32**), days to booting (-.41**), days to heading (-.39**) and days to flowering (-.43**) while showed significant positive correlation with days to flag leaf senescence (.33**). Significant positive correlation was found between $SPAD_1$ and $SPAD_2$ (.65**), between $SPAD_1$ and $SPAD_3$ (.49**) and between $SPAD_2$ and $SPAD_3$ (.49**). Similarly root from basket experiment showed significant positive correlation with canopy temperature depression (.33**) and significant negative correlation with flag leaf area (.-35*). canopy temperature depression showed significant positive correlations with physiological maturity (.28**).

Table 2: Pearson's correlation coefficient among different traits under late sowing condition at Rampur, Chitwan (2016/2017)

	fla	ph	nog	bm	ti	hi	tkw	dtb	dth	dtf	fls	mph	nor	rl	ctd	$SPAD_1$	$SPAD_2$	$SPAD_3$	rab	y
fla	1																			
ph	.344**	1																		
nog	0.061	0.183	1																	
bm	.408**	.503**	0.092	1																
ti	0.088	0.031	-0.050	.470**	1															
hi	-0.017	-0.040	0.167	-.431**	-.396**	1														
tkw	.263**	.296**	-.324**	.353**	0.017	0.157	1													
dtb	-.375**	0.073	0.132	-0.051	0.014	-.306**	-.414**	1												
dth	-.326**	0.104	0.056	-0.055	0.004	-.345**	-.392**	.917**	1											
dtf	-.286**	0.089	0.068	-0.055	0.028	-.356**	-.429**	.897**	.956**	1										
fls	0.158	.385**	-0.139	0.141	-0.098	-0.091	.326**	.203*	.267**	.233*	1									
mph	0.146	.363**	-0.165	0.128	0.028	-0.016	.239*	0.060	0.117	0.063	.639**	1								
nor	0.089	.246*	0.182	0.107	-0.028	0.092	0.103	0.043	-0.024	-0.014	0.156	0.074	1							
rl	0.168	0.107	-.206*	0.132	0.138	0.029	0.145	-0.101	-0.002	0.022	-0.027	-0.070	0.049	1						
ctd	-0.037	0.170	-0.081	0.031	0.118	0.004	-0.017	0.038	-0.030	-0.067	0.074	.283**	0.071	0.010	1					
$SPAD_1$	.356**	.343**	.205*	.340**	0.035	-0.045	.206*	-.227*	-.229*	-.203*	0.072	0.078	0.129	0.125	-0.074	1				
$SPAD_2$	.287**	.391**	.294**	.405**	0.005	-0.003	.222*	-0.049	-0.032	-0.009	.209*	0.094	0.128	0.120	-.223*	.649**	1			
$SPAD_3$	.283**	.433**	0.111	.247*	0.080	-0.044	0.168	0.191	0.190	0.174	.397**	.425**	0.136	0.011	0.193	.488**	.488**	1		
rab	-0.349*	-0.115	0.008	-0.135	-0.199	0.265	0.113	-0.059	-0.074	-0.126	0.138	0.224	-0.204	-0.145	0.333**	0.024	0.077	0.042	1	
y	.325**	.402**	.261**	.531**	0.084	.516**	.468**	-.333**	-.392**	-.401**	0.014	0.071	0.189	0.137	0.028	.271**	.373**	0.185	0.169	1

fla: flag leaf area(cm^2), ph: plant height (cm), , nog: number of grain per spike, bm: biomass yield(ton ha^{-1}), ti: number of tiller m^{-2}, hi: harvest index, tgw: thousand kernel weight (gm), dtb; days to booting, dth: days to heading, dta: days to flowering, fls: days to flag leaf senescence, mph: days to maturity, nor: number of root, rl: root length (cm), ctd: canopy temperature depression at flowering (°C), $SPAD_1$: SPAD immediately after flowering, $SPAD_2$:SPAD 10 days after flowering, SPAD3: SPAD 20 days after flowering, , rab: root angle in basket condition and y: grain yield (ton ha^{-1})

3.2 Path analysis

Biomass weight had maximum positive direct effect on grain yield (0.961) followed by harvest index (0.885), days to booting (0.183), days to flowering (0.122), SPAD 20 days after flowering (0.089), root angle of basket condition (0.069), number of root (0.051), number of grains per spike (0.045), and number of tiller per meter square (0.007). Some researchers also reported the high and positive direct effect of biomass yield and harvest index on grain yield (Leilah and Al-Khateeb, 2005). Positive direct effect of harvest index on grain yield was also supported (Majumder et al., 2008). On the other hand, days to booting (-0.406), flag leaf area(-0.074), physiological maturity (-0.057), SPAD immediately after flowering (-0.0043), SPAD 10 days after flowering (-0.030), root length (-0.025), days to flag leaf senescence (-0.017), Plant height (-0.013), canopy temperature 10 days after flowering (-0.010), and thousand kernel weight (-0.006) showed the negative direct effect on grain yield. Negative direct effect of plant height on grain yield was also reported (Aycicek and Yildirim, 2006).

Direct contribution of plant height to grain yield is negative i.e -0.013 but indirectly positive contribution to biomass (0.484), number of grain per spike (0.008), days to heading (0.019), days to flowering (0.011), number of root (0.012), and $SPAD_3$ (0.039) to the grain yield. Flag leaf area has direct negative contribution to the grain yield but indirectly increase biomass yield, number of grain per spike, $spad_3$ which ultimately increase the grain yield. Thousand kernel weight has to contribute to the grain yield. Similarly, days to flag leaf senescence has direct negative contribution (-0.017) to grain yield but indirectly increase $SPAD_3$ (0.038) to the grain yield.

Table 3: Path Coefficient analysis among different traits under late sowing condition at Rampur, Chitwan (2016/2017)

	fla	ph	nog	bm	ti	hi	tkw	dtb	dth	dtf	fls	mph	nor	rl	ctd	SPAD1	SPAD2	SPAD3	rab
fla	**-0.074**	-0.026	-0.005	-0.030	-0.007	0.001	-0.020	0.028	0.024	0.021	-0.012	-0.011	-0.007	-0.012	0.003	-0.026	-0.021	-0.021	0.026
ph	-0.004	**-0.013**	-0.002	-0.006	0.000	0.001	-0.004	-0.001	-0.001	-0.001	-0.005	-0.005	-0.003	-0.001	-0.002	-0.004	-0.005	-0.005	0.001
nog	0.003	0.008	**0.045**	0.004	-0.002	0.008	-0.015	0.006	0.003	0.003	-0.006	-0.007	0.008	-0.009	-0.004	0.009	0.013	0.005	0.000
bm	0.392	0.484	0.088	**0.961**	0.452	-0.414	0.339	-0.049	-0.053	-0.053	0.136	0.123	0.103	0.127	0.030	0.327	0.389	0.237	-0.130
ti	0.001	0.000	0.000	0.003	**0.007**	-0.003	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.001	-0.001
hi	-0.015	-0.035	0.148	-0.381	-0.350	**0.885**	0.139	-0.271	-0.305	-0.315	-0.081	-0.014	0.081	0.026	0.004	-0.040	-0.003	-0.039	0.234
tkw	-0.002	-0.002	0.002	-0.002	0.000	-0.001	**-0.006**	0.002	0.002	0.003	-0.002	-0.001	-0.001	-0.001	0.000	-0.001	-0.001	-0.001	-0.001
dtb	0.152	-0.030	-0.054	0.021	-0.006	0.124	0.168	**-0.406**	-0.372	-0.364	-0.082	-0.024	-0.017	0.041	-0.015	0.092	0.020	-0.077	0.030
dth	-0.060	0.019	0.010	-0.010	0.001	-0.063	-0.072	0.168	**0.183**	0.175	0.049	0.021	-0.004	0.000	-0.005	-0.042	-0.006	0.035	-0.014
dtf	-0.035	0.011	0.008	-0.007	0.003	-0.043	-0.052	0.109	0.117	**0.122**	0.028	0.008	-0.002	0.003	-0.008	-0.025	-0.001	0.021	-0.015
fls	-0.003	-0.007	0.002	-0.002	0.002	0.002	-0.006	-0.003	-0.005	-0.004	**-0.017**	-0.011	-0.003	0.000	-0.001	-0.001	-0.004	-0.007	-0.002
mph	-0.008	-0.021	0.009	-0.007	-0.002	0.001	-0.014	-0.003	-0.007	-0.004	-0.037	**-0.057**	-0.004	0.004	-0.016	-0.004	-0.005	-0.024	-0.013
nor	0.005	0.012	0.009	0.005	-0.001	0.005	0.005	0.002	-0.001	-0.001	0.008	0.004	**0.051**	0.002	0.004	0.007	0.006	0.007	-0.010
rl	-0.004	-0.003	0.005	-0.003	-0.003	-0.001	-0.004	0.003	0.000	-0.001	0.001	0.002	-0.001	**-0.025**	0.000	-0.003	-0.003	0.000	0.004
ctd	0.000	-0.002	0.001	0.000	-0.001	0.000	0.000	0.000	0.000	0.001	-0.001	-0.003	-0.001	0.000	**-0.010**	0.001	0.002	-0.002	-0.003
$SPAD_1$	-0.015	-0.015	-0.009	-0.015	-0.002	0.002	-0.009	0.010	0.010	0.009	-0.003	-0.003	-0.006	-0.005	0.003	**-0.043**	-0.028	-0.021	-0.001
$SPAD_2$	-0.009	-0.012	-0.009	-0.012	0.000	0.000	-0.007	0.001	0.001	0.000	-0.006	-0.003	-0.004	-0.004	0.007	-0.019	**-0.030**	-0.015	-0.002
$SPAD_3$	0.025	0.039	0.010	0.022	0.007	-0.004	0.015	0.017	0.017	0.015	0.035	0.038	0.012	0.001	0.017	0.043	0.043	**0.089**	0.004
rab	-0.024	-0.008	0.001	-0.009	-0.014	0.018	0.008	-0.004	-0.005	-0.009	0.009	0.015	-0.014	-0.010	0.023	0.002	0.005	0.003	**0.069**
Total	0.325	0.402	0.261	0.531	0.084	0.516	0.468	-0.391	-0.392	-0.401	0.014	0.071	0.189	0.137	0.028	0.271	0.373	0.185	0.169

fla: flag leaf area(cm^2), ph: plant height (cm), , nog: number of grain per spike, bm: biomass yield(ton ha^{-1}), ti: number of tiller m^{-2}, hi: harvest index, tgw: thousand kernel weight (gm), dtb; days to booting, dth: days to heading, dta: days to flowering, fls: days to flag leaf senescence, mph: days to maturity, nor: number of root, rl: root length (cm), ctd: canopy temperature depression at flowering(°C), $SPAD_1$: SPAD immediately after flowering, $SPAD_2$:SPAD 10 days after flowering, $SPAD_3$: SPAD 20 days after flowering and rab: root angle in basket condition.

4. Conclusion

Correlation studies showed that flag leaf area, plant height, number of grain per spike, biomass yield, harvest index, thousand kernel weight, SPAD at the time of flowering and 10 days after flowering are significant and positive association with grain yield. Path analysis revealed that number of tiller per m^{-2}, harvest index, days to heading and flowering, number of root, SPAD at 20 days after flowering, root angle in basket condition. Biomass yield, harvest index, thousand kernel weight, plant height, SPAD 10 days after flowering, flag leaf area, SPAD immediately after flowering and number of grain per spike could be the major selection criteria in breeding program as they have direct effects on grain yield and positively correlated with grain yield.

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