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Research Article

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Correlation and path coefficient analysis for grain yield and its attributing traits of maize inbred lines (*Zea mays* L.) under heat stress condition

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Abstract

Heat stress during the flowering, pollination and grain filling periods affect maize grain yield and its attributing traits. Twenty maize inbred lines were evaluated in alpha lattice design with two replications under heat condition during spring season from February to June, 2016 at Rampur, Chitwan, Nepal. Meterological data showed maximum mean temperature (46.2–43.28°C) and minimum (30.52-30.77°C) in with relative humidity 37.05 to 49.45% inside the tunnel during in April-May which coincided with the flowering, pollination and grain filling periods. The data were analyzed statistically to study the correlation and path coefficient. The analysis of variance showed that all the lines were significantly different from each other for all traits anthesis silking interval, SPAD chlorophyll and leaf senescence, tassel blast, leaf firing, plant and ear height, leaf area index, ear per plant, cob length and diameter, number of kernel ear^{-1}, number of kernel row^{-1}, number of kernel row, silk receptivity, shelling percentage, thousand kernel weight and grain yield. Grain yield had positive and significant phenotypic correlation with silk receptivity, shelling percentage, cob length and diameter, number of kernel ear^{-1}, number of kernel row^{-1}, number of kernel row, SPAD chlorophyll, thousand kernel weight and significant and negative correlation with tassel blast, anthesis silking interval, leaf area index, leaf firing. Path analysis revealed that of thousand kernel weight, shelling percentage, number of kernel ear^{-1} and silk receptivity exerted maximum positive direct effect on grain yield. Therefore, selection of genotypes having maximum thousand kernel weight, shelling percentage, silk receptivity and number of kernel ear^{-1} and shorter anthesis silking interval, no leaf firing and tassel blast is pre-requisite for attaining improvement in grain yield under heat stress condition.

Keywords: Maize (*Zea mays L.*), Heat stress, Correlation, Path analysis, Coefficient

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Introduction

Maize being nutritionally animportant crop has multiple functions in thetraditional farming system; being used as food andfuel for human beings andfeed for livestock andpoultry. In Nepal, it is grown in 8,91,583 ha producing 2.2 million tons, with an average yield of 2500 kg ha^{-1} (MOAD, 2016). The reasons for low maize yield in Nepal are high temperature, drought, stalk rot infestation, maize borer and shoot fly infestation, poor crop management, high input rates and use of low quality, substandard seed.

Heat and drought stress have emerged as a common problem worldwide which can reduce maize crop productivity (Ali et al., 2015). Heat stress in the flowering and grain filling periods due to elevated temperatures drastically affect crop productivity. A record drop in maize production was reported in many maize-growing areas of the world (Van der Velde et al., 2010). It is predicted that maize yield might be reduced up 70 % due to increasing temperatures (Khodarahmpour et al., 2011). A report of the Asian Development Bank warns that if the current trends persist until 2050 major food crop yields and food production capacity of south Asia will significantly decreases by 17% for maize,12% for wheat and 10% for rice due to climate change induced heat and water stress.

Maize crop yield potential grown in terai is always at risk from important biotic and abiotic stresses which limit crop production. Now day's heat stress is one of key abiotic stress with high potential impact on maize crop growth and development and eventually on productivity. Various plant organs, in a definite hierarchy and in interaction with each other are involved in determining crop yield under stress (Barnabas et al., 2008). The response of maize crop to climate depended on the genetic and physiological make up of variety being grown and interaction with prevailing climatic condition. Therefore, incomparasion to agronomic management genetic management of heat stress tolerance genotypes would be low economic input technology that would be readily acceptable to resource's –poor, heat affected and small land holding farmer (Saxena and Toole, 2002).

Transitory or constantly high temperatures cause an array of morph-physiological, anatomical and biochemical changes in plants, which eventually affects plant growth and development, and lead to a drastic reduction in biological and economic yield (Commuri and Jones, 2001). The correlation studies measure the associations between yield and other traits. Path coefficient analysis permits the

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separation of correlation coefficient into direct and indirect effects. Therefore, the present investigation was carried out to determine the association of traits with grain yield through correlation coefficient and direct and indirect effect of a set of variables through path analysis under heat stress condition in maize.

Materials and Methods

The research was conducted at National Maize Research Program (NMRP) of Rampur, Chitwan during spring season from February 24, 2015 to July 2016, geographically located at 27º 37' North Latitude and 84 º 29' East longitude at an altitude of 225 meter above sea level. This site contains only sandy loam soil with acidic reaction. This research location is characteristics of subtropical climate. The plant materials were collected from National Maize Research Program (NMRP). The list of inbred lines along with pedigree information included in the study is presented in Table 1.

Field experiment was conducted in alpha lattice design. There were two conditions: normal and plastic house (for heat stress), each condition replicated twice. Each replication comprised four blocks consisting of five plots each. Each plot was 3 meter in length 0.6 meter wide. Each plot had one row with spacing 20 cm between rows, inter block gap was 0.5 m was maintained. Each plot contained single row with spacing 60×20 cm and consisted 15 hills, each of two seed were sown, one of whose seedling were removed at the six leaves stage. The dose of chemical fertilizer applied was 120:60:40 kg NPK per hectare. Fertilizer were applied prior to sowing at rate of 60 kg N ha^{-1}, 60 kg P and 40 kg K ha^{-1} and additional side dressing of 30 kg N ha^{-1} were applied at the two times in six leaves stage and knee high stage of maize. The irrigation was done three important stage, knee high stage, tasseling stage and milking stage. To created heat stress condition maize study half of field was controlled heating imposed using two plastic (120gsm) houses were used two week just prior to the onset of reproductive period up to the crop harvesting. Maximum mean temperature 46.2°C in April in heat stress condition whereas as normal condition was 37.23°C and similarly for May month in maximum mean temperature was 43.28°C whereas in normal condition 34.54°C at time of flowering, pollination and grain filling periods as shown in Table 2. Partial opening top side of tunnel was done for control relative humidity inside tunnel to avoid any possible disease outbreak.

Data Collection

Data on days to50% anthesis, days to 50% silking and ears per plot, leaf firing, tassel blast, leaf senescence were recorded on plot basis. Whereas, ear height (cm), number of kernel ear^{-1}, number of kernel row, number of kernel row^{-1}, SPAD reading, leaf area index, silk receptivity, thousand kernel weight (g)and shelling per cent were recorded on five selected representative plants. The sample cobs were shelled, cleaned and grain weight and shank weight were recorded to calculate the shelling percent. Thousand kernel weight was measured by counting 1000 grains from the bulk of each plot after shelling and weighed in grams after the moisture was adjusted to 15%. Anthesis-silking interval (ASI) was calculated by subtracting the number of days taken for 50% anthesis from the number of days taken to 50% silk emergence.

Table 1. Names and pedigree information of maize inbred lines used for heat stress research at NMRP Chitwan (2016).

S.N	Maize Inbred Lines	Pedigree	S.N	Maize Inbred Lines	Pedigree
1	NML-2	CML-430	11	RL–101	UPAHAR-B-20-2-3-1-1
2	RML–4	CA00326	12	RML–24	CA00304
3	RML–32	CA00320	13	RML–40	CML-427
4	RML–95	PUTU-17	14	RML–57	CLQG6602
5	RML–86	PUTU-20	15	RL–107	UPAHAR-B-20-2-4-3-1
6	RML–17	CML-287	16	RML–20	CA-34503
7	RML–96	AG-27	17	RML–76	CLRCYQ007
8	RL–105	UPAHAR-B-20-2-4-1-1	18	RML–7	CML-413
9	RL–111	UPAHAR-B-31-1-1-1-1	19	RML–91	PUTU-19
10	RML–115	PUTU-17	20	RL–140	POOL-21-12-1-2-2-1-1

Table 2. Weather data recorded in NMRP, Chitwan during Experimental period (24th Feb to June 2016).

Months	Maximum Temperature (°C)	Minimum Temperature (°C)	Mean (°C)	Relative Humidity (%)
Feb	26.98	12.38	19.68	81.29
March	32.05	17.55	24.80	65.82
April Normal	37.23	23.83	30.53	56.36
April Stress	46.20	32.52	39.36	37.05
May Normal	34.54	22.16	28.35	67.72
May Stress	43.28	30.77	37.03	49.45
June	33.99	24.90	29.44	78.32

Source: National Maize Research Program (NMRP), NARC, Chitwan

Leaf area index was calculated by total leaf area divided by land area and multiply by correction factor (0.75). Silk receptivity was recorded by total number of fertilized grains per ear divided by number of potential grain per ear. Leaf firing was obtained by the counting the number of plants that showed leaf firing symptoms in the total number of plants in a particular plot and was expressed in percentage. Tassel blast was obtained by the counting the number of plants that showed tassel blast symptoms in the total number of plants in particular plot was expressed in percentage. Grain yield (kg/ha) at 15% moisture content was calculated using fresh ear weight with the help of the below formula:

$$\text{Grain yield}\ (\frac{kg}{ha}) = \frac{F.W.\ (\frac{kg}{plot}) \times (100 - HMP) \times S \times 10000}{(100 - DMP) \times NPA}$$

Where,

F.W. = Fresh weight of ear in kg per plot at harvest

HMP = Grain moisture percentage at harvest

DMP = Desired moisture percentage, i.e. 15%

NPA = Net harvest plot area, m^2

S = Shelling coefficient, i.e. 0.8

This formula was also adopted by Carangal et al. (1971) and Shrestha et al. (2015) to adjust the grain yield (kg ha^{-1}) at 15% moisture content. This adjusted grain yield (kg ha^{-1}) was again converted to grain yield (t ha^{-1}).

Statistical Analysis

The data recorded on different parameters from in heat stress field were first tabulated and processing in Microsoft excel (MS- Excel, 2010), then subjected to restricted maximum likelihood (REML) tool in GenStat to obtain ANOVA. Correlation coefficients of different traits were carried out using the formula given by Steel and Torrie, (1980) by using SPSS program. Path analysis carried out by using MS- Excel.

Results and Discussion

Maximum mean temperature 46.2°C in April in heat stress condition whereas as normal condition was 37.23°C and similarly for May month in maximum mean temperature was 43.28°C whereas in normal condition 34.54°Cmeans mean temperature 8-9°C higher in plastic house at time of flowering, pollination and grain filling periods as well as there was no drought due to plot was irrigated when the surface began dry and all other factor were kept constant, the only stress led to difference between the normal and stress treatment was assumed to be due to heat stress. Analysis of variance was performed for all traits. Analysis of variance of mean square comparison described significant difference among 20 maize inbred lines for traits as shown in Table 3 and 4.

Anthesis-silking interval (ASI)

In present study, significant increases the ASI under heat stress as compared to normal condition was observed. Mhike et al., (2012) also reported similar result significant increases the ASI in maize under heat stress might be silking delay i.e due to at rise in temperature (+30C), pollen shedding starts much ahead of silks emergence while silking is delayed, so that silking period does not correspond to anthesis/tasseling, resulting in poor synchronization of flowering. Cicchino et al (2010) reported mechanisms of increases anthesis silking interval under heat stress condition causes reduction in essential nutrients as well as all other factors like pollen viability, increase silking day known as silk delay. Edmeades et al., (1993) reported association of short anthesis-silking interval with increased partitioning of assimilate to the ear at flowering and supply of nitrogen to the developing ear a cause of improved performance of genotypes under stress environment.

Leaf firing and Tassel blast

Leaf firing of the flag leaf and one or two adjacent leaves was observed after severe heat waves that occurred when the tassel tissue was about to emerge from the leaf whorl. Thus occurrence of tassel blastinfluences the occurrence leaf firing under heatstress condition due increase in cell injury leads to release of reactive oxygen species complexes and leakage of electrolytes which leads to chlorosis, and death of the tissue under high temperature. Chen et al., (2010) also reported that under high temperature stress condition leaf firing reduces photosynthetic apparatus which lead to reduction in grain yield. Maize pollen viability decreases with exposure to temperatures above 35 °C (Dupuis and Dumas, 1990). Dass et al., (2010) reported that high temperature can delay anthesis and damage most of tassels resulting in little or no pollen production and increasing the occurrence of male sterile plants in field.

SPAD chlorophyll and leaf senescence

In heat stress condition, leaf sensensedue to increase in cell injury leads to release of reactive oxygen species complexes and leakage of electrolytes which leads to chlorosis, and death of the tissue, leading to inappropriate production of assimilates which are required for proper growth. Crafts-Brandner et al., (2002) reported reduced content of chlorophyll might cause a drastic reduction in the efficiency of the photosynthetic machinery of crop plants due to reduction in activation of rubisco enzyme alters rate of ribulose-1,5-biphosphate regeneration by disruption of electron transport and inactivation of oxygen evolving enzymes of PS II. Plant senescence is a common physiological phenomenon which leads to drying of the leaves but in heat stress phenomenon proceeds at faster rate moving towards the flag leaf by destroying the chlorophyll content. Guendouz et al., (2012) reported that plant having high chlorophyll content showed slow leaf senescence and produces maximum yield under heat stress condition. Renu et al., (2004) reported that plant having heat tolerant was characterized by less cell injury percentage under heat stress condition.

Plant and Ear Height

Effect of heat stress was most prominent on plant and ear height reduction might be result of the effect of heat stress on internal –nodal elongation. This research finding was supported by (Weaich et al., 1996 and Cairns et al., 2012).

Leaf area index (LAI)

Leaf area index of the decreases was observed after severe heat waves due to leaf growth pattern of maize increases in rang of temperature 0-35ºC with decline at 35-40ºC. Leaf area expansion is of great importance for light interception and for photosynthesis; it varies with the quantity of assimilates allocated to the production of leaves and the ratio of the leaf area produced per unit of leaf dry matter. Heat stress causes translocation of the photosynthetic products cannot fully match the increased rates of carbon fixation under the prevailing conditions, this results in the thickening of the existing leaves and the formation of thicker new leaves, and therefore in a sharp decrease of leaf area in the pre-anthesis period. It can also be noted that the LAI is maximum at tasselling or later and further slight decrease in leaf area is attributed to the senescence of the old (thinner) leaves, so that the younger thicker leaves remain on the stand a and longer growing cycle and normally a higher LAI and determine the overall LAI value. This finding was agreement with earlier finding reported by (Danalatos et al., 1994). Karim et al., (2000) also noted that leaf area and day time leaf expansion rate were good thermo tolerance trait of tropical maize under heat stress condition.

Ear Per Plant (EPP)

Significant increases in the frequency of barrenness in high temperature due reduction in average ears per plant was observed. It is attributed to the fact that different vegetative and reproductive organs undergo active growth at the same stage, which incurs competition for assimilates among organs. Rattalino Edreira et al., (2011) finding was agreement with earlier finding reported as changes in distribution of assimilates might be cause for reduced reproductive growth, particularly ears per plant. Cicchino et al., (2010b) reported thatsimilar findings has been reported in previous studies in maize crop exposed to high temperature at flowering stage.

Number of kernel per ear (NKE^{-1})

A number of factors could be responsible for reduction in number of kernels ear^{-1} under heat stress condition. Duke and Doehlert, (1996) and Rattalino Edreira et al., (2011) finding was agreement with earlier finding reported as number of kernel per ear reduces due to reduced pollen viability and receptivity of silk, increased frequency of kernel abortion, decreased cell division in endosperm, reduced sink capacity of developing kernels, reduced starch grain number and overall starch synthesis, increased soluble sugar accumulation, duration of grain filling, kernel development and enzyme activities. Cicchino et al., (2010b) reported similar finding that stress in pre-anthesis stress leading to barrenness in plants, while absorption of fertilized structure and reduced ear growth rate lead to reduction in kernel number and ultimate affect crop yield. Moser et al., (2006) reported that stress before and immediately after pollination may lead to failure of number of kernel development ear. Hussain et al. (2010) also reported that, number of rows cob^{-1}, number of kernels row^{-1} and yield per plant were much reduced in spring season due to heat stress.

Silk Receptivity

Pollen shed may occurs for up to 2 weeks but usually lasts for 5 to 8 days with peak shed by about days 3.Silk can grow 2 to 3 inch per day and maximum growth by 3 and 4 days after first silk. Silk longevity is around 10 days and maximum up to 14 days but under heat stress condition desiccate the prematurely will appear as erratic pattern of fertilization along the ear with most fertilized ovule located at the base. A number of factors could be responsible for reduction in number of silk receptivity under heat stress on corn kernel set, seasonal pollen production, silk elongation pattern and duration of silk receptivity. The seasonal pollen production determine kernel per plant at pollen densities less than 3000 pollen grain per silk. It was found that a minimum pollen shed density per exposed silk is required to achieve maximum kernel set and grain yield reported by (Westgate et al., 2003). Silk receptivity can be drastically reduced by as much as 80% during high temperatures due tosudden pollen shedding over a very short time (Fonseca et al., 2005). Anderson et al., (2004) found that kernel set and yield stability are impacted by variation among hybrid for silk elongation and senescence. Campos et al., (2004) suggested that selection based on performance in multi- environment trials increased grain yield under drought trough increase yield potential and kernel set, rapid silk exertion and reduced barrenness through at lower rate than under optimal condition.

Shelling percentage

Rowhani et al., (2011) reported that significant variation in shelling percentage under heat stress condition might be associated with lower grain yield traits such as pollen viability and fertilization under high temperature. This was because of grain filling period was most sensitive to heat stress as reported by (Thompson,1986).

Thousand Kernel weight (TKW)

Rise in temperature beyond 30°C impacts the activity of *Rubisco* in maize, which in turn reduces photosynthesis and ultimately decreases grain filling period and grain size (Steven et al., 2002). Kernel weight is influenced by source-sink relationships during grain fill with increased kernel weight being caused by irradiance level, grain-fill duration, and plant and kernel growth rate (Gambinet et al., 2006). The reduction of thousand kernel weight in agreement with findings (Abendrothet et al., 2011).

Grain Yield

Maize yields have been shown to have an optimum growing temperature of 29 °C and 30 °C, respectively; temperatures above this threshold result in yield decreases (Schlenkerand Roberts, 2009). The major effect of high temperature is embryo abortion, which is related to the inhibition of photosynthesis and the subsequent reduction in assimilates available to developing kernels. Exposure to temperatures above 30 °C damaged cell division and amyloplast replication in maize kernels which reduced the size of the grain sink and ultimately yield (Commuri and Jones, 2001). The of the yield decrease up to 100%, larger than those estimated in previous studies (Lobell and Field, 2007; Schlenker and Roberts, 2009). Lobell and Field, (2007) showed maize yields decreased 8.3% per 1°C rise without any complicating effect due to water stress. Khodarahmpour et al., (2011) observed reduction of grain yield up to 70% under heat stress might be due to low pollen viability, silk receptivity and longer ASI duration in heat stressed condition.

Correlation Analysis

The grain yield had positive and significant phenotypic correlation with silk receptivity, shelling percentage, cob length and diameter, number of kernel ear^{-1}, number of kernel row ear^{-1}, number of kernel ear^{-1}, SPAD chlorophyll, and thousand kernel weight whereas it was significant and negative correlation with tassel blast, anthesissilking interval, leaf area index, leaf firing under heat stress condition as shown in Table 5. Khodarahmpourand Choukan, (2011) reported similar finding in a study of fifteen inbred line under heat stress condition reported that grain yield had positive and significant correlation with number of kernel ear^{-1}, no of kernel row, no of kernel ear^{-1}, 1000-grain weight, and cob diameter. Kaur et al., (2010) reported similar result significant negative association leaf firing and tassel blast with grain yield under heat stress. Cairnset al.,(2012) reported significant correlation between grain yield and ASI and SPAD reading was negatively correlated. Krasensky, J., and Jonak, C. (2012) reported similar result for significant positive for association between chlorophyll content and grain yield under drought stress. Betran et al.,(2003a) reported similar result for SPAD chlorophyll content and

EPP with grain yield under drought stress but relation of EPP was found non-significant.

Path Coefficient Analysis

Direct effect of thousand kernel weight (0.786), shelling percentage (0.552), number of kernel ear^{-1} (0.448), silk receptivity (0.279),leaf area index (0.058) on grain yield had highest positive value as compared to all other traits such as ear per plant (0.011)exerted positive direct effect on yield based on direct effect in path analysis but it is non-significant correlated with grain yield hence may not be statistically considerable. El-Badawy et al., (2011) reported similar result highest positive direct effect of 100 grain weight on yield per plant in maize. Krishnaji et al., (2017) found similar result high positive direct effect of shelling percentage and number of kernel per ear under heat stress condition. Jawaria Azhar, J., RamzanandAhmad, R.M. (2016) reported similar result high positive direct effect of thousand kernel weight on grain yield under heat stress condition in maize. Similarly correlation coefficient of SPAD chlorophyll, cob diameter, cob length, Number of kernel row ear^{-1}, number of kernel row were positiveand significant with grain yield while there direct effects on grain yield were negative. But negative direct effects of these traits were nullified by their positive indirect contribution via other yield components. Similarly correlation coefficient of leaf area index was negative and significant with grain yield while there direct effects on grain yield were positive. But positive direct effects of these traits were nullified by their negative indirect contribution via other yield components. On contrary, some characterof anthesis silking interval and tassel blast exerted positive direct effect on grain yield. However positive direct effect of these traits was nullified by their negative indirect contribution via other yield components. Thousand kernel weight showed the highest positive indirect contribution towards grain yield via shelling percentage (0.4960), number of kernel per ear (0.381), silkreceptivity (0.260), anthesis silking interval (0.126),ear height(0.0380) and leaf firing (0.015). However, it showed negative indirect effect via tassel blast, leaf senescence, SPAD chlorophyll, leaf area index, ear per plant, cob diameter and length, number of

Table 3. Mean square comparison for different traits in 20 inbred lines of maize under high temperature stress at NMRP, Rampur, Chitwan (2016).

Source of vaiance	df	ASI	LF	TB	LS	SPAD	EH	LAI	EPP
REP.Block	6	0.76ns	29.58ns	10.36ns	0.98ns	8.45ns	24.38ns	0.03ns	0.015ns
Inbred line	19	2.96*	251.3*	369.75**	473.03**	80.83*	264.92**	0.5*	0.16*
Error	13	0.69	92.58	105.7	0.26	29.45	29.34	0.107	0.03

Table 4. Mean square comparison for different traits in 20 inbred lines of maize under high temperature stress at NMRP, Rampur, Chitwan (2016).

Source of vaiance	df	SR	CD	CL	NKRE	NKE	NKR	SP	TKW	GY
REP.Block	6	2.46ns	0.07ns	0.14ns	0.07ns	0.521ns	0.52ns	2.11ns	91ns	189.9ns
Inbred line	19	465.98**	4.10**	69.13**	63.3**	86.83**	86.84**	465.98**	39025**	169314**
Error	13	12.96	0.06	0.798	0.23	1.118	1.11	12.96	100	743

Table 5. Pearson's Correlation coefficient among different traits under heat stress condition at NMRP, Rampur (2016).

	ASI	LF	TB	LS	SPAD	EH	LAI	EPP	SR	CD	CL	NKRE	NKE	NKR	SP	TKW
ASI	1															
LF	.546*	1														
TB	.641**	.328	1													
LS	-.442	-.113	-.031	1												
SPAD	-.555*	-.607**	-.474*	-.063	1											
EH	.109	-.054	.389	-.051	-.386	1										
LAI	.345	.101	.474*	.021	-.238	.508*	1									
EPP	.094	-.137	.052	-.140	-.282	.251	-.161	1								
SR	-.788**	-.723**	-.714**	.195	.617**	-.246	-.457*	-.093	1							
CD	-.860**	-.687**	-.686**	.317	.629**	-.311	-.411	-.039	.937**	1						
CL	-.758**	-.626**	-.761**	.320	.496*	-.260	-.339	-.026	.869**	.907**	1					
NKRE	-.852**	-.705**	-.715**	.258	.640**	-.266	-.464*	-.038	.954**	.972**	.871**	1				
NKE	-.682**	-.748**	-.714**	.117	.513*	-.153	-.396	-.052	.953**	.853**	.831**	.884**	1			
NKR	-.848**	-.710**	-.745**	.234	.648**	-.333	-.488*	-.038	.956**	.968**	.873**	.987**	.887**	1		
SP	-.763**	-.630**	-.605**	.292	.572**	-.236	-.463*	-.180	.945**	.883**	.803**	.910**	.846**	.901**	1	
TKW	-.854**	-.668**	-.743**	.340	.609**	-.330	-.446*	-.047	.932**	.982**	.937**	.978**	.850**	.975**	.898**	1
GY	-.726**	-.692**	-.679**	.167	.560*	-.237	-.445*	-.132	.980**	.896**	.857**	.917**	.941**	.917**	.963**	.904**

Values are significant difference at 5 % level of significance (*) and highly significant at 1 % level of significant (**), ASI= AnthesisSilkinginterval,LF %= leaf firing%,TB= Tassel blast,LS=Leaf senescence,SPAD=SPAD chlorophyll,EH=Ear height,PH=Plant height,LAI= leaf area index,EPP= Ear per plant,SR%= Silk receptivity,CD=Cob diameter,CL=Cob length,NKRE=Number of kernel per row,NKE=Number of kernel per Ear,NKR=Number of kernel per row,SP%= Shelling percentage, TKW=Thousand kernel weight(g),GY=GrainYield(Kg ha^{-1}).

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Table 6. Direct (diagonal) and indirect effects of different traits on grain yield.

	ASI	LF	TB	LS	SPAD	EH	LAI	EPP	SR	CD	CL	NKRE	NKE	NKR	SP	TKW
viaASI	**0.022**	-0.081	-0.095	0.065	0.082	-0.016	-0.051	-0.014	0.116	0.127	0.112	0.126	0.101	0.125	0.113	0.126
via LF	-0.012	**-0.022**	-0.007	0.003	0.014	0.001	-0.002	0.003	0.016	0.015	0.014	0.016	0.017	0.016	0.014	0.015
viaTB	0.062	0.032	**0.096**	-0.003	-0.046	0.037	0.046	0.005	-0.069	-0.066	-0.073	-0.069	-0.069	-0.072	-0.058	-0.072
viaLS	0.077	0.020	0.005	**-0.173**	0.011	0.009	-0.004	0.024	-0.034	-0.055	-0.055	-0.045	-0.020	-0.041	-0.050	-0.059
viaSPAD	0.047	0.052	0.040	0.005	**-0.085**	0.033	0.020	0.024	-0.053	-0.054	-0.042	-0.054	-0.044	-0.055	-0.049	-0.052
viaEH	-0.013	0.006	-0.045	0.006	0.044	**-0.115**	-0.058	-0.029	0.028	0.036	0.030	0.031	0.018	0.038	0.027	0.038
viaLAI	0.020	0.006	0.027	0.001	-0.014	0.029	**0.058**	-0.009	-0.026	-0.024	-0.020	-0.027	-0.023	-0.028	-0.027	-0.026
viaEPP	0.001	-0.001	0.001	-0.002	-0.003	0.003	-0.002	**0.011**	-0.001	0.000	0.000	0.000	-0.001	0.000	-0.002	-0.001
viaSR	-0.220	-0.202	-0.199	0.054	0.172	-0.069	-0.128	-0.026	**0.279**	0.262	0.243	0.267	0.266	0.267	0.264	0.260
viaCD	0.202	0.161	0.161	-0.074	-0.148	0.073	0.097	0.009	-0.220	**-0.235**	-0.213	-0.228	-0.200	-0.227	-0.207	-0.231
viaCL	0.056	0.046	0.056	-0.024	-0.036	0.019	0.025	0.002	-0.064	-0.067	**-0.073**	-0.064	-0.061	-0.064	-0.059	-0.069
viaNKRE	0.243	0.201	0.204	-0.074	-0.182	0.076	0.132	0.011	-0.272	-0.277	-0.248	**-0.285**	-0.252	-0.281	-0.259	-0.279
viaNKE	-0.305	-0.335	-0.320	0.052	0.230	-0.069	-0.177	-0.023	0.427	0.382	0.372	0.396	**0.448**	0.397	0.379	0.381
viaNKR	0.358	0.300	0.314	-0.099	-0.273	0.140	0.206	0.016	-0.403	-0.408	-0.368	-0.416	-0.374	**-0.422**	-0.380	-0.411
via SP	-0.422	-0.348	-0.334	0.161	0.316	-0.130	-0.256	-0.099	0.522	0.488	0.444	0.503	0.467	0.498	**0.552**	0.496
via TKW	-0.671	-0.525	-0.584	0.267	0.479	-0.259	-0.351	-0.037	0.733	0.772	0.737	0.769	0.668	0.766	0.706	**0.786**
SUM	-.726**	-.692**	-.679**	0.1674	.560*	-0.237	-.445*	-0.132	.980*	.896*	.857**	.917**	.941**	.917**	.963**	.904**

kernel row per ear and number of kernel per row respectively. Shelling percentage exhibited had positive indirect contribution on grain yield via thousand kernel weight, number of kernel per ear, silk receptivity, ear height, leaf firing and anthesis silking interval. However, it showed negative indirect effect via tassel blast, leaf senescence, SPAD chlorophyll, leaf area index, ear per plant, cob diameter and length, number of kernel row per ear and number of kernel per row respectively. Number of kernel per ear exhibited had positive indirect contribution on grain yield via thousand kernel weight, shelling percentage, silk receptivity, anthesis-silking interval, ear height, and leaf firing. However, it showed negative indirect effect via tassel blast, leaf senescence, SPAD chlorophyll, leaf area index, ear per plant, cob diameter andlength, number of kernel row ear^{-1} and number of kernel row^{-1}respectively. Silk receptivity exhibited had positive indirect contribution on grain yield via thousand kernel weight, shelling percentage, anthesis silking interval, ear height, and leaf firing. However, it showed negative indirect effect via tassel blast, leaf senescence, SPAD chlorophyll, leaf area index, ear per plant, cob diameter and length, number of kernel row ear^{-1} and number of kernel row^{-1}respectively.The negative correlation between grain yield and anthesis silking interval, tassel blast and leaf area index indirect influence via thousand kernel weight and shelling percentage, silk receptivity and number of kernel ear^{-1}.This traits needs consideration, because direct effect these traits positive in direction. The positive correlation between grain yield and SPAD chlorophyll, cob diameter, cob length, number of kernel row^{-1} and number of kernel row indirect influence via thousand kernel weight and shelling percentage, silk receptivity and number of kernel ear^{-1}. This trait needs consideration, because direct effect these traits negative in direction.

Conclusion

In present investigation, SPAD reading, cob diameter and length, thousand kernel weight, silk receptivity, shelling percentage, number of kernel ear^{-1} with minimum tassel blast, leaf firing, shorter anthesis-silking interval were most yield determinative traits as revealed from correlation analysis and hence simultaneous selection for these trait might brining an improvement in maize grain yield under heat stress. Beside the correlation analysis inter se association also provide huge support on these traits from all other yield components. Path analysis using grain yield as dependent variable revealed that of thousand kernel weight, shelling percentage, number of kernel ear^{-1}, silk receptivity exerted maximum positive direct effect on grain yield and these trait could be relied upon for selection of genotypes to improve grain yield. On contrary, some character via anthesis silking interval and tassel blast exerted positive direct effect on grain yield. However positive direct effect of effective theses trait were nullified by their negative effects through other components traits thousand kernel weight, shelling percentage, silk receptivity and number of kernel ear^{-1} which ultimately resulted in to highly significant negative correlation with grain yield.

Hence indirect selection through other component characters with which these two traits exhibited negative indirect effects can be recommended so as to bring improvement in grain yield. Thus selection of genotypes having maximum thousand kernel weight, shelling percentage, silk receptivity and number of kernel ear^{-1} and minimum anthesis silking interval, leaf firing, tassel blastis pre-requisite for attaining improvement in grain yield under heat stress condition.

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