International Journal of Agriculture & Biology
ISSN Print: 1560–8530; ISSN Online: 1814–9596
17–0296/2018/20–2–333–337
DOI: 10.17957/IJAB/15.0493
http://www.fspublishers.org

***Full Length Article***

# Characterization of Indigenous and Exotic Maize Hybrids for Grain Yield and Quality Traits under Heat Stress

**Muhammad Irfan Yousaf, Khadim Hussain, Shahid Hussain, Aamir Ghani, Muhammad Arshad, Aamer Mumtaz and Rana Abdul Hameed**
*Maize and Millets Research Institute, Yusafwala, Sahiwal, Pakistan*
*For correspondence: Irfanpbg.uaf@gmail.com

## Abstract

Heat stress is a major environmental constraint in crop production, worldwide. Identification and selection of suitable cultivars and traits for high temperature tolerance is vital to produce heat resilient genotypes. To find out superior genotypes and plant parameters, 14 maize hybrids of local and exotic origin, were evaluated under heat stress conditions. Evaluation of maize genotypes was done for morphological, phenological and quality related traits i.e., days to 50% tasseling, days to 50% silking, plant height, cob height, cob length, thousand grain weight, protein contents, oil contents, shelling (%) and grain yield under heat stress. Results revealed presence of high genetic variability among maize hybrids for yield and quality related traits. Association analysis showed that thousand grain weight (0.6328*) cob height (0.5982*) and protein contents (-0.5259*) had significant relationship with grain yield. Principal component and biplot analysis were performed to assess genetic diversity and heat tolerance among maize genotypes. Locally bred hybrids FH-988, FH-922, FH-1046 and YH-1898 were found to be the most heat tolerant hybrids and possessed maximum diversity for yield and quality related traits under heat stress. These results could be implied for characterization and further improvement of maize germplasm to produce heat resilient maize genotypes. 

**Keywords:** Protein; PCA; Oil; Biplots; Grain quality

## Introduction

Maize is the 3rd most important cereal crop of Pakistan after wheat and rice. It is grown primarily for feed (65%) in poultry and livestock sector and for human consumption (35%). It also provides fuel and raw material for different industrial products viz., alcohol based beverages, starch, oil, protein, food sweeteners, cosmetics and pharmaceuticals (Reddy and Jabeen, 2016). It contributes 0.4% in GDP and 2.2% to value addition. It was cultivated on an area of 1144 thousand hectares with 4.920 million tons' produce and an average yield of 4301 kg/ha (Economic Survey of Pakistan, 2015-2016). In Pakistan per hectare yield of maize (4.29 metric tons/ha) is lower than many maize growing countries like USA (10.73 metric tons/ha), Argentina (8.20 metric tons/ha), Canada (9.36 metric tons/ha) and China (5.81 metric tons/ha) (USDA, 2016).

Heat stress is the major climatic factors that severely affect crop production. Being a $C_4$ plant, maize efficiently uses solar radiations and produces higher yields with wider adoptability. However, crop growth and development get reduced under elevated temperature (≥35°C) (Rahman *et al.*, 2013; Ur-Rehman *et al.*, 2015). In maize, grain yield may get reduced up to 101 kg $ha^{-1}$ $day^{-1}$ when temperature reaches near 35°C at pollination and grain filling stage (Rahman *et al*., 2013). Heat stress delayed tasseling and silking time in maize by increasing anthesis-silking interval (ASI) which ultimately reduce grain yield as a result of poor fertilization and seed setting (Struik *et al*., 1986; Fonseca and Westgate, 2005; Cicchino *et al*., 2010; Dass *et al*., 2010). Grain yield is positively correlated with thousand grain weight, that is highly influenced by hyper thermal stress due to reduction in endosperm size and numbers (Jones and Brenner, 1987). Grain yield is reduced under heat stress due to overall reduction in leaf area, leaf elongation, photosynthetic activity and shoot biomass that ultimate reduces sink capacity (Watts, 1971). In recent years, a record drop in maize production have been reported in many maize growing areas of the world due to heat stress (Van der Velde *et al*., 2010). It is predicted that maize yield might be reduced from 15–50% due to increase in temperature in future in South Asia (Kumar *et al*., 2011).

Genetic variations present in cultivated germplasm provide the basis for genetic improvement of crops. Genotypes from warmer ecological zones are relatively more heat tolerant than those from cooler regions and can serve as base population for development of heat resilient genotypes (Yamamoto *et al*., 2011; Kugblenu *et al*., 2013). Higher tolerance level against heat stress is still not achieved due to minimum exploitation of genetic diversity (Paran and

**To cite this paper:** Yousaf, M.I., K. Hussain, S. Hussain, A. Ghani, M. Arshad, A. Mumtaz and R.A. Hameed, 2018. Characterization of indigenous and exotic maize hybrids for grain yield and quality traits under heat stress. *Int. J. Agric. Biol*., 20: 333–337

Van, 2007). Hence, there is much need to explore available germplasm for high temperature stress to select heat resilient genotypes. Therefore, present study was designed to explore genetic divergence present in endogenous and exotic germplasm for heat tolerance. Furthermore, heat resilient hybrids will be selected on the basis of yield performance under heat stress conditions.

## Materials and Methods

### Experimental Site and Details

The experiment was conducted on research area of Maize and Millets Research Institute, Yusafwala-Sahiwal during Spring, 2016. Fourteen maize hybrids were evaluated for yield performance under heat stress conditions (Table 1). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications having sixrows, each of five meter length and 0.75 m apart from other line. Crop was sown on 16$^{th}$ of March, 2016 in order that flowering and grain filling stages of crop face expected high temperature stress (more than 40°C). Sowing was done with the help of dibbler at 1 seed per hill and 15 cm seed-to-seed distance was maintained.

### Data Collection and Analysis

Data was collected for different morphological, phenological and grain quality traits viz., days to 50% tasseling (DT), days to 50% silking (DS), plant height (PH), cob height (CH), cob length (CL), thousand grain weight (TGW), protein contents % (PC), oil percentage (Oil %) shelling percentage (S %) and grain yield per hectare (GY). Protein and oil percentage were estimated by using Near infrared (Inframatic 9200 of Perten instruments, Sweden). Data was statistically analyzed for analysis of variance and correlation coefficient (Steel *et al*., 1997). Principal component and biplot analysis (Sneath and Sokal, 1973) were used to compute relationship among different heat-related plant parameters and to categorized indigenous and exotic maize hybrids for their heat tolerance by using two statistical software XLSTAT 14 and SPSS 16.0.

## Results

### Metrological Conditions

Metrological data showed that maize hybrids experienced heat stress throughout their lifespan especially during flowering and grain filling period. Average maximum temperature at flowering and grain filling period (May and June) remained 43.13°C and 44.1°C, which is much higher temperature than needed for optimum growth and development of maize crop (35°C). Reproduction stage of maize crop is very sensitive to higher temperature stress (≥ 35°C) (Fig. 1).

### Analysis of Variance and Correlation

Analysis of variance exhibited highly significant differences among maize hybrids for all traits under heat stress (Table 2). Association analysis showed the relationship between different plant traits and grain yield. Correlation analysis showed that grain yield had a significantly positive association with thousand grain weight (0.6328$^{*}$) and cob height (0.6328$^{*}$), while significantly negative association with protein contents (%) (-0.5259$^{*}$). Furthermore, significantly positive relationship was observed between days to 50% tasseling and days to 50% silking (0.9921$^{**}$). Cob height had significant and positive relationship with days to 50% tasseling (0.5602$^{*}$), days to 50% silking (0.5317$^{*}$) and plant height (0.5865$^{*}$). Significantly negative association was found between cob height and protein % (-0.5939$^{*}$) (Table 3).

### Principal Component and Biplot Analysis

Principal component analysis extracted 10 components based on morphological, phenological and grain quality traits, out of which five PC's depicted Eigen value more than 1 (Table 4).

First five principal components, PC1, PC2, PC3, PC4 and PC5 explained 37.14%, 18.50%, 13.35%, 11.16% and 10.63% variations in all traits, respectively. Cumulative variance of these five PCs was 90.78% in total variability of data. In PC1, most of the traits i.e., days to 50% tasseling, days to 50% silking, plant height, cob height, cob length, protein contents and grain yield contributed significantly in variations. In PC2, thousand grain weight and oil content significantly participated to variations, while from PC3, no parameter contributed significantly for variations. Shelling percentage illustrated significant variations in PC4 (64%), while no parameter contributed significantly in PC5 (Table 6). On the other hand, among hybrids, five hybrids: FH-988, FH-922, YH-5213, FH-949 and JPL-2066 depicted maximum variations in PC1 whereas in PC2 maximum divergence was shown by four hybrids YH-1898, FH-1046, NK-8711 and MV-531. In PC3, YH-5440, Maxima and P-1543 contributed towards maximum variations (Table 5 and 6).

PC1 and PC2 biplot explained 55.64% variation in grain yield, oil contents, protein contents, thousand grain weight, days to 50% silking, days to 50% tasseling and cob height while plant height and shelling percentage exhibited minimum differences (Fig. 2). Grain yield, oil contents, cob length, cob height and days to 50% tasseling were the most discriminating traits under heat stress due to their longer vector length. Furthermore, grain yield had positive and significant association with thousand grain weight, cob height, oil contents and cob length, while negative association with protein contents. PC1 and PC3 biplot described 50.49% diversity for thousand grain weight, protein contents, cob length, plant height, grain yield and

**Table 1:** Names of Maize hybrids and their origin

| Sr. No | Hybrid Name | Origin | Sr. No | Hybrid Name | Origin |
|---|---|---|---|---|---|
| 1 | FH-1046 | MMRI Yusafwala | 8 | YH-5140 | MMRI Yusafwala |
| 2 | FH-949 | MMRI Yusafwala | 9 | YH-5133 | MMRI Yusafwala |
| 3 | FH-922 | MMRI Yusafwala | 10 | YH-5440 | MMRI Yusafwala |
| 4 | FH-988 | MMRI Yusafwala | 11 | NK-8711 | Syngenta Seeds |
| 5 | JPL-2066 | JPL (Pvt.) Limited | 12 | P-1543 | Pioneer Seeds |
| 6 | YH-1898 | MMRI Yusafwala | 13 | Maxima | Agroman |
| 7 | YH-5213 | MMRI Yusafwala | 14 | MV-531 | Agroman |

**Table 2:** Analysis of variance (ANOVA) for morphological and phonological characters in maize hybrids

| SOV | d.f | DT | DS | PH | CH | CL | TGW | Pro. % | Oil % | S (%) | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 0.595$^{NS}$ | 0.286$^{NS}$ | 35.643* | 19.59** | 0.0112$^{NS}$ | 162.86$^{NS}$ | 0.002$^{NS}$ | 0.0007$^{NS}$ | 0.214$^{NS}$ | 56770$^{NS}$ |
| Genotypes | 13 | 26.96** | 26.54** | 426.58** | 364.19** | 0.9724** | 1509.5** | 2.775** | 0.267** | 21.09** | 6091144** |
| Error | 26 | 1.0311 | 1.2088 | 18.87 | 4.134 | 0.0096 | 121.80 | 0.0073 | 0.0030 | 0.829 | 177318 |
| Grand Mean | | 73.33 | 76.21 | 209.64 | 107.19 | 7.998 | 152.38 | 13.27 | 4.321 | 86.43 | 10386 |

* Significant at 5% probability level, ** significant at 1% probability level, NS= Non-significant
(DT=Days to 50% tasseling, DS=days to 50% silking, PH=plant height, CH=cob height, CL= Cob length, TGW= thousand grain weight, Pro. % = Protein content Percentage, Oil % = Oil content Percentage, S (%) = Shelling percentage, GY= Grain yield per hectare)

**Table 3:** Traits association for morhological and phonological characters in maize hybrid

| Traits | DT | DS | PH | CH | CL | TGW | Pro. % | Oil % | S (%) | GY |
|---|---|---|---|---|---|---|---|---|---|---|
| DT 50% | 1 | | | | | | | | | |
| DS 50% | 0.9921** | 1 | | | | | | | | |
| PH | 0.2341 | 0.1903 | 1 | | | | | | | |
| CH | 0.5602* | 0.5317* | 0.5865* | 1 | | | | | | |
| CL | -0.3689 | -0.3713 | -0.2721 | -0.1851 | 1 | | | | | |
| TGW | -0.0925 | -0.1262 | -0.2349 | -0.0152 | 0.0725 | 1 | | | | |
| Pro. (%) | -0.4155 | -0.4327 | -0.5142 | -0.5939* | 0.3576 | -0.0405 | 1 | | | |
| Oil (%) | -0.2306 | -0.2329 | -0.0599 | 0.3448 | 0.3924 | 0.2086 | -0.0963 | 1 | | |
| S (%) | -0.2075 | -0.1382 | -0.2334 | -0.1601 | 0.1470 | -0.1360 | -0.1902 | -0.0330 | 1 | |
| GY | 0.3682 | 0.3288 | 0.3400 | 0.5982* | -0.3943 | 0.6328* | -0.5259* | 0.1541 | -0.1816 | 1 |

*Significant at 5% probability level, ** Significant at 1% probability level, NS = Non-significant
Significance is shown by bold letters

**Table 4:** Eigenvalue, factor variability (%) and cumulative variability (%) of different factors in maize hybrids under heat stress

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Eigenvalue | 3.7144 | 1.8500 | 1.3347 | 1.1157 | 1.0627 | 0.4900 | 0.2790 | 0.0989 | 0.0511 | 0.0036 |
| Variability (%) | 37.1437 | 18.5005 | 13.3473 | 11.1571 | 10.6270 | 4.8998 | 2.7895 | 0.9887 | 0.5109 | 0.0356 |
| Cumulative % | 37.1437 | 55.6442 | 68.9914 | 80.1485 | 90.7755 | 95.6752 | 98.4648 | 99.4535 | 99.9644 | 100.0000 |

cob height, which were also the most discriminating traits (Fig. 3). In this biplot, thousand grain weight, cob height, days to 50% tasseling and silking had significant positive relationship with grain yield, however, negative association was found between grain yield and cob length (Fig. 2–3).

## Discussion

Elevation in temperature is a major limiting factor in crop productivity. Globally, evaluation and selection of heat tolerant maize germplasm is obvious for producing heat resilient genotypes because it is the only source available for breeding programs. Different techniques are being applied to evaluate and select heat tolerant germplasm in maize (Molin *et al*., 2013; Carvalho *et al*., 2004). Among these, principal component analysis gets the advantage of being more precise and informative. Principal component analysis retrieves minimum number of components having maximum variations in data. Correlation studies add in effective selection of genotypes on the basis of association of traits among themselves and with grain yield.

Plant height (Traore *et al.*, 2000; Chen *et al.*, 2012), days to tasseling (Cicchino *et al.*, 2010), days to silking (Kaur *et al.*, 2010; Ordóñez *et al.*, 2015), cob height (Shrestha *et al.*, 2014), thousand grain weight (Tahir *et al.*, 2008; Khodarahmpour, 2011), shelling percentage (Rahman *et al.*, 2013), reduces photosynthesis ability (Steven *et al.*, 2002) and grain yield (Hussain *et al.*, 2006) have been extensively used by researchers to evaluate maize germplasm under heat stress. In current study, these traits had significant variations among maize hybrids under heat stress. Correlation analysis revealed that selection of parents

**Table 5:** Contribution of Maize hybrids from different origin in genetic diversity for yield and yield related morphological and phonological traits under heat stress

| Genotypes | F1 | F2 | F3 | F4 | F5 |
|---|---|---|---|---|---|
| FH-1046 | 1.3036 | 28.6007 | 0.2111 | 5.1997 | 2.5909 |
| FH-949 | 7.4233 | 3.3247 | 1.0951 | 2.9413 | 12.5733 |
| FH-922 | 17.1781 | 0.9051 | 0.4155 | 10.2889 | 1.5472 |
| FH-988 | 34.4910 | 0.1437 | 0.4984 | 7.3886 | 1.0782 |
| JPL-2066 | 1.9364 | 2.5963 | 0.0742 | 2.5608 | 2.4484 |
| YH-1898 | 0.5885 | 24.6979 | 0.1107 | 6.9931 | 0.3110 |
| YH-5213 | 18.3557 | 0.0739 | 7.9918 | 8.9773 | 15.7568 |
| YH-5140 | 0.2472 | 0.1653 | 3.7801 | 14.2668 | 20.7527 |
| YH-5133 | 3.8900 | 1.0855 | 3.7389 | 27.4787 | 1.4885 |
| YH-5440 | 0.9561 | 2.6123 | 29.6796 | 3.8976 | 0.2355 |
| NK-8711 | 0.9032 | 19.3489 | 9.7825 | 1.1602 | 13.0350 |
| P-1543 | 1.5199 | 1.8615 | 7.6490 | 0.7617 | 9.2181 |
| Maxima | 6.8307 | 3.9248 | 26.7689 | 0.2807 | 2.9642 |
| MV-531 | 4.3761 | 10.6593 | 8.2043 | 7.8046 | 16.0002 |

Figures presented in bold showed maximum contribution of Hybrids in the respective Principal Component

**Table 6:** Contribution of different plant characteristics in genetic diversity for yield and yield related morphological and phonological traits in maize under heat stress

| Characters | F1 | F2 | F3 | F4 | F5 |
|---|---|---|---|---|---|
| Days to 50% Tasseling | 17.7992 | 5.9971 | 2.0187 | 0.2401 | 17.7212 |
| Days to 50% Silking | 16.8581 | 7.2215 | 1.4093 | 0.0114 | 20.0553 |
| Plant height | 9.7387 | 0.0006 | 13.4823 | 6.7400 | 25.8201 |
| Cob height | 17.8168 | 4.2074 | 9.0126 | 2.3790 | 1.5975 |
| Cob length | 8.2348 | 5.5385 | 7.5465 | 2.7547 | 21.1951 |
| Thousand grain weight | 0.0599 | 28.6464 | 27.7665 | 3.6929 | 0.0299 |
| Protein contents (%) | 14.5455 | 1.2188 | 8.0219 | 14.2652 | 1.5903 |
| Oil contents (%) | 0.0792 | 30.4340 | 11.6860 | 3.0308 | 8.3639 |
| Shelling percentage (%) | 1.4193 | 0.3908 | 11.8824 | 64.4872 | 1.4663 |
| Grain yield | 13.4485 | 16.3448 | 7.1737 | 2.3985 | 2.1604 |

Figures presented in bold showed maximum contribution of plant characters in the respective Principal Component

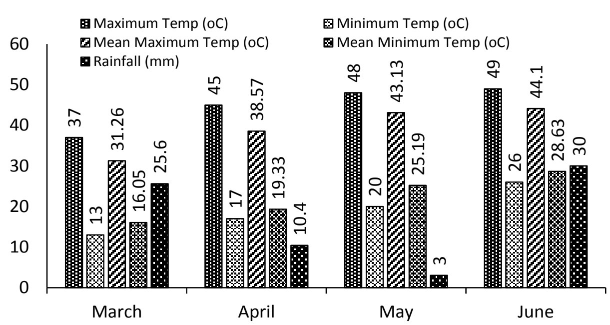


**Fig. 1:** Metrological data of spring season (March to May)

should be based upon cob height, 1000 grain weight and protein contents because these traits were significantly associated with grain yield under elevated temperature stress. Similar results were reported by many scientists which showed association of grain yield with protein contents (Saleem *et al.*, 2008) cob height, plant height and 1000 grain weight (Kumar *et al.*, 2015; Reddy and Jabeen, 2016).

Principal component analysis was also used by many

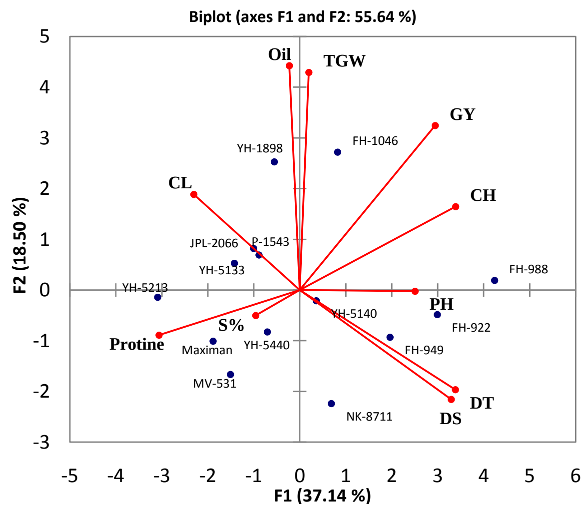


**Fig. 2:** Biplot of PC1 and PC2 showing relationship of different traits and maize hybrids

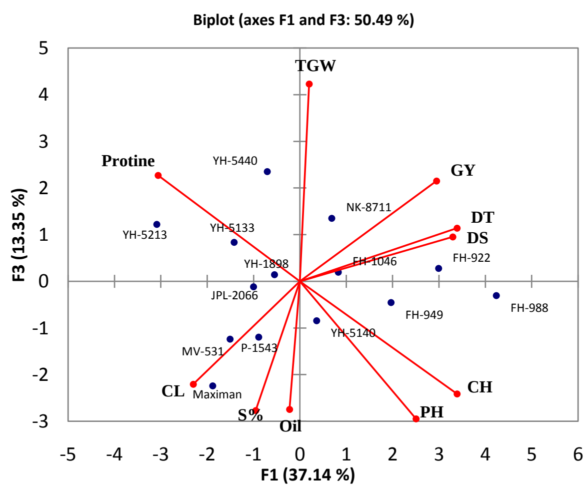


**Fig. 3:** Biplot of PC1 and PC3 showing relationship of different traits and maize hybrids

researchers to evaluate and categorize maize germplasm (Qi-Lun *et al.*, 2008; Iqbal *et al.*, 2015). Principal component analysis suggested that days to 50% tasseling and silking, cob height, protein contents, oil contents and thousand grain weight were the major contributing traits towards variations in present study. Therefore, these traits could be taken as selection criteria for improving maize under heat stress. Moreover, among hybrids, six indigenous hybrids; FH-988, YH-5213, FH-922, FH-1046, YH-1898, YH-5440 and one exotic hybrid NK-8711 contributed maximum in total variability in studied germplasm. Biplots analysis revealed that local hybrids: FH-988, FH-922, FH-1046 and YH-1898 were the most heat tolerant hybrids, because they produced more yield under stress conditions and are away for base, in line with discriminating traits.

No exotic hybrid was as heat tolerant. Biplot analysis exposed that indigenous hybrids were superior in quality than of exotic hybrids. Local hybrid YH-5213was superior for protein contents (14.90%) followed by YH-5133 (14.4%) and YH-5440 (14.13%). Similarly, oil contents were highest in YH-5140 (4.80%) and YH-1898 (4.76%) under high temperature stress. This shows that indigenous germplasm could be utilized to improve production and quality of maize genotypes under heat stress. Furthermore, local germplasm could be used to produce genotypes having heat resilience, high protein, high oil contents and adoptable to hotter climatic conditions and will serve as source population in future breeding programs.

## Conclusion

High level of genetic variability was present among maize hybrids for morpho-phenological and grain quality related traits under heat stress. Similarly, associations of grain yield were found with cob height, thousand grain weight and protein contents. Furthermore, endogenous hybrids (FH-988, FH-922, FH-1046 and YH-1898) showed more heat tolerance over exotic hybrids and were superior in terms of yield and quality. These results could be implied for characterization and further improvement of maize germplasm to produce heat resilient maize genotypes.

## Acknowledgments

We thank Dr. Waseem Akbar and Hafiz Muthar Javeed for providing moral support and K. Shashok (Author AID in the Eastern Mediterranean) for improving the language of the manuscript.

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**(Received 15 March 2017; Accepted 04 October 2017)**