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EFFECTS OF POST HARVEST DRYING ON KERNEL QUALITY OF MAIZE

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ABSTRACT

To overcome the prevailing vitamin A deficiency, provitamin A biofortified maize hybrids were introduced by CIMMYT in Pakistan. Provitamin A carotenoids are sensitive to light and temperature therefore, careful handling is prerequisite. Conventionally direct sun drying of cobs is practiced in the region after harvesting but there was need to optimize the post-harvest drying conditions to retain the nutritional value in biofortified maize hybrids. Direct and indirect sun drying was practiced in current study to evaluate the nutritional losses caused by direct exposure to sun light. Current experiment was conducted under completely randomized design with two factor factorial treatment structure with two replications. Experimental treatments were direct and indirect post-harvest sun drying of cobs. Experimental results showed that starch contents were affected negatively in maize cobs by direct exposure to sun light for drying. Losses in starch contents resulted in proportional increase of protein and oil contents in maize hybrids. Ash contents were also increased in direct sun drying of maize cobs relative to indirect (shade) sun drying. Significant losses of total carotenoid and pro-vitamin A contents were observed under direct exposure to sun light. Carotenoid pigment losses were attributed to susceptibility to oxidative damage and light absorption capacity. Indirect or shade drying harbored the favorable results to retain the optimal kernel quality traits. Among all studied exotic hybrids, HP1097-15 and HP1097-16 were more stable because these were subjected to minimum losses in kernel quality traits under direct sun drying. HP1097-15 was also high yielding based on grain yield among the tested hybrids. It is recommended that indirect (under shade) post-harvest drying of cobs should be practiced to avoid the nutritional losses in pro-vitamin A biofortified maize hybrids.

Keywords: Pro-vitamin A Biofortified, Shade, sundry, moisture, carotenoids, proteins, starch, shelf-life

INTRODUCTION

Maize is mostly harvested at higher grain moisture contents to avoid field losses due to on-farm drying and also to same time for preparation of field for next crop or to escape terminal harsh temperature. On field drying of maize is done under natural conditions for storage, industrial processing and preparing the feed for animals. Grains are stored to use as seeds for sowing, stored in gene banks to facilitate the researchers & breeders or stored by processing industrial units for prolonged utilization. To facilitate the intended milling processes, large number of industrial units also subject the grains to artificial drying to attain the desirable moisture contents (Islam *et al*., 2004). However, any issue, stress or mismanagement during field or artificial drying could cause the deterioration of grains in the form of quality losses, breakage and stress cracking (Shoughy *et al*., 2009). Different drying methods like sun drying, solar drying (different devices are used to manipulate solar radiations for drying) and oven drying are commonly used for drying of food crops. Manipulation of the drying method is dependent on the nature of food crop and level of the moisture to be attained. Dried maize grains are processed to produce the flour which can be reconstituted into dough or paste for production of different food items. Working principal in the background of different grain drying methods is the evaporation of moisture. Removal of moisture has variable effects on nutritional profile of food items (Hassan *et al.,* 2007). Retention of high nutritional value with increased shelf life is prerequisite for prolonged consumption of food items. Drying of food items also prevent the growth of microorganisms and avoid the deterioration (Mukhtar, 2009).

Besides macronutrient like, protein, starch and oil, there are many other micronutrients in maize grain particularly carotenoids. Maize kernel has both pro-vitamin A carotenoids and non-provitamin A carotenoids. The xanthophylls *like* lutein and zeaxanthin are non-provitamin A carotenoids which constitutes major proportion of the kernel carotenoids. β-carotene, β-cryptoxanthin and α-carotene are provitamin A carotenoids or vitamin A precursors (Wurtzel *et al*., 2012). Wide range of genetic diversity is reported in total carotenoid contents of yellow maize kernels as Egesel *et* *al.,* (2003) reported the range of total carotenoid contents from 0.15 to 51.4 µgg^{-1} on dry weight basis. Carotenoids have light absorption property due to chromophore polienic chain. Chromophore of seven or higher number of conjugated double bonds enable the light absorption in visible spectrum. Polienic chain system of carotenoid is also seriously posing the susceptibility for oxidative damage and geometrical isomerization frequently caused by light and heat (Boon *et al.,* 2010). This susceptibility of carotenoids for oxidative damage is a serious challenge for attaining the targets for pro-vitamin A biofortification. Increase of pro-vitamin A contents in maize kernels through biofortification are rendered ineffective by oxidative deterioration through heat and light. To retain the effectiveness of provitamin A bioforified maize, avoidance of carotenogenic damage during drying of kernels is prerequisite. Quantification of carotenogenic losses during different traditional drying methods is necessary to recommend the safest drying method. Wide range of genetic studies were already conducted for genetic improvement of agronomic and quality traits (Aslam *et al*., 2017; Sanghamitra *et al*., 2017) on pro Vitamin A biofortified maize however, no such study has been conducted to evaluate the quality losses in pro vitamin A biofortified maize during conventional post-harvest drying, at least in the case of Pakistan where the current study was carried out. The study targeted to estimate the nutritional losses during two different drying methods for exotically introduced pro-vitamin A biofortified maize hybrids.

MATERIALS AND METHODS

Sixteen different provitamin A biofortified maize hybrids were introduced and evaluated at University of Agriculture Faisalabad, Pakistan in collaboration with International Maize and Wheat Improvement Center (CIMMYT)-Pakistan under USAID-funded Agricultural Innovation Program (AIP) for Pakistan. These hybrids were evaluated during spring season-2016 (planting was done in mid February) at the research area of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. Faisalabad is geographically located at latitude of 31.4181 ºN, longitude of 73.0776 ºE and altitude of 184.4 m from sea level. Soil preparation for trial was done by ploughing two times and using rotavator for final preparation. Ridge (75cm apart) sowing was done manually by labor in irrigated field while 2nd irrigation was done one week later. Management practices, irrigations, fertilization and nutrient supplementations were done according to recommended production technology. Two bags of DAP and one bag of potash sulphate was applied at the time of sowing while three bags of urea were applied during progressing vegetative growth stages. Ears of each hybrid entry were harvested during 1st week of June, 2016 separately and subjected to further drying treatments.

All of the sixteen pro-vitamin A biofortified maize hybrids were distinct and have different moisture contents at time of harvesting. Moisture contents of subjected 17 (16 provitamin A biofortified + 1 local check) maize hybrids at the time of harvesting were estimated using moisture meter (Dickey John MULTIGRAIN) and further drying experiment was conducted to attain the moisture contents ranging 10-12%. Local check was used in field trial and same was also used as local check in drying experiment. Cobs drying experiment was conducted under completely randomized design under two factor factorial treatment structures with two replications. Ears of each genotype were equally divided into four parts on weight basis because there were two treatments and each with two replications. Ear drying treatments were direct sun drying and indirect sun drying (shade drying). Direct sun drying was carried out by directly exposing the maize cobs to sun light after removing the husk. Indirect sun drying was done by packing the de-husked cobs in craft paper bags and exposing these bags to sun shine (shade or covered drying). This sun drying experiment was conducted during the month of June by following a similar practice used by farmers in the Punjab province of Pakistan who harvest their maize crop mainly in the month of June. Average daily outside temperature at the site of experiment was 44ºC, 43ºC, 44ºC, 42ºC, 40ºC, 42ºC and 42ºC from 10-June-2016 to 16-June-2016 respectively. Experimental treatments were applied for the period of 10 hrs (8:00AM to 6:00PM) daily for one week whereas, after daily treatment dose, all experimental units were kept in warehouse to protect them from animals, dew and rain. Moisture contents of the kernel were estimated on daily basis by randomly selecting the kernels from three rows of different cobs from each experimental unit. Similar procedure was continued until the moisture contents were reached 10-12% of total biomass.

After completion of direct and indirect sun drying experiment, different nutritional quality parameters were estimated from each experimental unit separately. Percent contents of protein, starch, moisture, oil and ash were estimated along with total carotenoids contents (µg/g) and total pro-vitamin A carotenoid (µg/g) contents of kernels. Near infrared (NIR) spectroscopy was used for non-destructive estimation of protein, oil, starch and moisture percentage. Data for protein, starch, oil and moisture percentage were estimated by running samples through Inframatic 9100 (Perten instruments, Inc. IL) according to procedure of method no. 39-11 described in AACC (2000). Moisture percentage was also estimated by moisture meter (Dickey John MULTIGRAIN). Total carotenoid contents (µg/g) were estimated spectrophotometrically whereas, total pro-vitamin A contents (µg/g) comprising of mainly β-carotene and β-cryptoxanthin were estimated using the high performance liquid chromatography (HPLC) protocol recommended and devised by Howe and Tanumihardjo, (2006). Total carotenoid contents were estimated by following protocol established by Rodriguez-Amaya and Kimura, (2004).

Total Carotenoid Contents (µg/g) =

$$\frac{A_{(total)} \times volume\ (ml) \times 10^4}{A^{1\%}_{1cm} \times Sample\ Weight\ (g)}$$

Whereas, $A_{(total)}$: absorbance, volume: total volume of extract (25ml), $A^{1\%}_{1cm}$: absorption coefficient of 2500.

Statistical analysis: Analysis of variance (Steel and Torrie, 1980) for two factor factorial treatment structure was estimated by using Statistix 8.1 software. Tukey's Honestly Significant Difference (HSD) test was used for treatment mean comparison and genotypic mean comparison (Tukey, 1953). Principal component analysis (PCA) biplots were used for accessing the correlation among different traits under both drying conditions (Gabriel, 1971).

RESULTS AND DISCUSSION

Analysis of variance showed the significant differences among maize hybrids for protein, moisture, starch, oil, ash, total carotenoid and pro-vitamin A contents. These traits were significantly different under two different drying treatments. Treatment × genotype interaction was also significant for all studied quality traits of maize kernel (Table 1). Partitioning of variance showed that these hybrids were distinctive from each other for quality perspective. Significance of treatment effects also showed that two different drying methods distinctively affected the performance of quality traits of maize kernels.

Treatment mean comparison showed that moisture, starch, total carotenoid contents and pro-vitamin A contents were significantly higher under indirect sun drying (shade drying) treatment while protein, oil and ash contents were higher under direct sun drying treatment (Table 1). Actually there were proportional changes in the macronutrients under different drying treatments. Starch contents were reduced in maize kernel under direct sun drying (Table 1). Setiawan *et al*., (2010) also reported that under direct sun drying conditions endogenous enzyme activity is involved in hydrolysis of starch. Reduction of starch and moisture contents resulted in proportional increase of protein, oil and ash contents of the maize hybrids under direct sun drying as measurements were taken on percent basis. Stability of crude protein in maize kernel has also been reported however, amino acid composition was reported to be changed. Ash contents were lower in maize hybrids under indirect sun drying and higher under direct sun drying. Bhuiyan *et al.,* (2010) also reported that under higher storage or drying temperature, proportion of ash and dry matter contents is increased in maize kernels.

Direct sun drying was accompanied with direct exposure to sun light and relatively increased temperature which were responsible for deterioration of total carotenoids and provitamin A contents (Table 1). Antioxidant capacity of carotenoids in maize kernels is mainly responsible for carotenogenic loses due to increased activity of reactive oxygen species under direct exposure to sun light (Cantrell *et al.,* 2003). It was also visually evident that yellow kernel pigments were degraded or faded under direct sun drying (Figure 1). Degradation of carotenogenic pigments in maize kernels could be attributed to increased production of abscisic acid under stress condition and also to non-specific mechanisms like, photo chemical oxidation (Zhai *et al*., 2016). Losses in total carotenoid and provitamin A contents under direct sun drying is attributed to susceptibility of carotenoid to oxidative damage imposed by sun light. Light is responsible for oxidative degradation and geometrical isomerization of carotenoid pigments as it is clearly evident by pigment losses in current study. Retention of higher nutritional components like provitamin A carotenoids is essential to get the nutritional benefits and prevent malnutrition against vitamin A deficiency.

Variability in genotypic responses showed that every genotype is not equally responsive to particular conditions due to differences in their genetic background. Provitamin A biofortified maize hybrids used in current study showed the means for proximate composition comparable to Ujabadeniyi and Adebolu, (2005), and Carddsd *et al.,* (2015). Significance of treatment mean comparison, dictated the assessment of genotypic mean comparison for viewing the across treatment effects. Genotypic means for particular traits across both drying treatments were given in Table (2). Significant variability was found for different traits in current study whereas, previously it was reported that Pakistani maize genotypes were reported to have proximate compositional traits like ash contents ranging 0.70 to 1.30%, fats ranging 3.21 to 7.71%, proteins ranging 7.70 to 14.60%, and carbohydrates ranging 69.65 to 74.54% (Ikram Ullah *et al.,* 2010).

Percent change in means of different studied traits was estimated by considering the direct sun drying as stress treatment and indirect sun drying as normal treatment. Percent change in protein contents of maize hybrids ranged from -7.48 to 5.94% for HP1097-10 and HP1097-7 respectively. Whereas percent changes in protein % in LC-1 was 8.33%. Change in moisture percent was ranging from -0.901% to -6.42% for biofortified maize hybrids while -6.84% for LC-1. Losses in starch contents were ranged 0.00% to -0.72% in different maize hybrids. Oils contents also showed the increasing or decreasing trends and percent changes were ranging from -5.41% to 7.32%. Ash percentage was increased in most cases with few exceptions only. Losses of total carotenoid and provitamin A contents were ranging from -26.38% (HP1097-20) to 10.67% (HP1097-16) and -25.07% (HP1097-14) to -1.26% (HP1097-13) respectively (Table 2). Among all studied provitamin A biofortified maize hybrids, HP1097-15 and HP1097-16 were most stable to drying treatments based on the current performance (Table 2). Bhuiyan *et al.,* (2010) reported the increase of ash contents and reduction of crude protein in maize grains by drying kernels at elevated temperature. In corroboration with our findings, Awad and Mustafa, (2014) also reported that ash, fat and protein contents were higher in maize flour under shade drying conditions relative to sun drying.

Biplot graphs based on PCA components (Gabriel, 1971) were used for visualizing the correlation among different studied traits under both drying treatments. Angle between the trait vectors was used to elucidate the correlation between traits. Acute angle (<90º) between trait vectors showed positive correlation, right angle (=90º) between vectors showed independence or no correlation and obtuse angle (>90º) between trait vectors showed negative correlation. Correlation studies in current experiment for shade drying and sun drying treatment showed that total carotenoid contents and provitamin A contents were positively correlated (Figure 2 & 3). Protein % and Ash % were positively correlated, and starch% was positively correlated with moisture% under sun drying treatments (Figure 3). Maqbool *et al*., (2016) also used PCA based biplots for correlation analysis and reported that correlation among the traits and indices were changed under different stress conditions.

Although quality traits have huge importance but knowing the on field yield performance greatly improves the genetic gains. In current study same set of the hybrids were also evaluated in field for grain yield performance. Grain yield was estimated for 10% of moisture contents. Variability was observed for grain yield across the genotypes. It can be seen that HP1097-1, HP1097-2, HP1097-4, HP1097-5, HP1097-6, HP1097-8, HP1097-13, HP1097-14, HP1097-15 and HP1097-21 were having grain yield more than 4.00 t/h and also more than local check (LC-1; Figure 4). Maqbool *et al*., (2017) also evaluated the maize genotypes and reported significant variability for grain yield across the genotypes.

In conclusion, direct sun drying of provitamin A biofortified maize hybrids has deteriorative effects on the composition of proximate profile, total carotenoid and provitamin A contents. Starch contents, total carotenoids and provitamin A carotenoids were negatively affected by direct sun drying. Shade drying harbored the favorable results to retain the optimum kernel quality traits. Among all studied exotic hybrids, HP1097-15 and HP1097-16 were more stable because these were subjected to minimum losses in kernel quality traits under direct sun drying. Besides quality losses, grain yield of HP1097-15 (4.55 t/h) was higher than HP1097-16 (3.33 t/h). Therefore, HP1097-15 was found to be one of the high yielding hybrids and relatively more stable for quality traits. It is also inferred that direct sun drying of provitamin A biofortified maize hybrids to attain the desirable moisture percentage is not recommended to be practiced by farmers. Alternatively post-harvest drying of cobs under proper shade is recommended to avoid the losses of quality traits. However, there is also need to explore the potential safety for nutritional quality (micro and macronutrients) of maize seed during drying in commercial dryers.

Table 1. Analysis of variance and Tukey HSD All-Pairwise treatment mean comparisons for different quality traits of provitamin A biofortified maize hybrids

Analysis of Variance								
SOV	Df	Protein %	Moisture %	Starch %	Oil %	Ash %	TCC	Pro-VA
Replication	1	0.0200	0.0050	0.0401	0.00125	0.0035	0.106	0.0542
Treatments	1	0.5000**	3.5555**	1.5312**	0.06125**	4.2535**	126.45**	19.57**
Genotypes	16	3.4218**	0.2347**	4.1175**	0.51553**	0.6567**	90.346**	50.85**
T × G	16	0.1324**	0.0667**	0.0386**	0.05213**	0.1637**	27.783**	4.678**
Error	33	0.0086	0.0121	0.0124	0.00211	0.0029	0.041	0.0517
Tukey HSD All-Pairwise treatment mean comparisons								
Shade drying		10.75 (B)	10.75 (B)	10.75 (B)	10.75 (B)	10.75 (B)	10.75 (B)	10.75 (B)
Sundrying		10.92 (A)	10.92 (A)	10.92 (A)	10.92 (A)	10.92 (A)	10.92 (A)	10.92 (A)
A		0.05	0.05	0.05	0.05	0.05	0.05	0.05
Standard Error for Comparison		0.0218	0.0218	0.0218	0.0218	0.0218	0.0218	0.0218
Critical Value for Comparison		0.0442	0.0442	0.0442	0.0442	0.0442	0.0442	0.0442

Where, TCC: Total carotenoid contents (µg/g), Pro-VA: Pro-vitamin A carotenoids (µg/g)

Table 2. Tukey HSD All-Pairwise genotype × treatment mean comparisons and percent changes across the treatments.

	Protein %			**Moisture %**			**Starch %**			**Oil %**		
Genotypes	Shade	Sundry	**% change**	Shade	Sundry	**% change**	Shade	Sundry	**% change**	Shade	Sundry	**% change**
HP1097-1	10.80	11.00	1.85	11.00	10.50	-4.55	70.80	70.50	-0.42	3.70	3.60	-2.70
HP1097-2	10.60	10.70	0.94	11.20	10.90	-2.68	70.40	70.20	-0.28	4.10	4.40	7.32
HP1097-3	10.90	11.20	2.75	10.70	10.30	-3.74	70.00	69.50	-0.71	3.80	4.09	7.05
HP1097-4	10.00	10.30	3.00	11.10	11.00	-0.90	71.30	71.30	0.00	4.20	4.00	-4.76
HP1097-5	11.00	11.20	1.82	11.50	11.10	-3.48	70.90	70.80	-0.14	3.70	3.50	-5.41
HP1097-6	10.50	10.70	1.90	11.20	10.50	-6.25	71.50	71.00	-0.70	3.50	3.60	2.86
HP1097-7	10.10	10.70	5.94	11.00	10.70	-2.73	70.70	70.30	-0.57	4.50	4.60	2.22
HP1097-8	10.30	10.70	3.88	11.00	10.50	-4.55	71.00	70.70	-0.42	4.00	4.20	5.00
HP1097-10	10.70	9.90	-7.48	11.10	10.50	-5.41	70.70	70.60	-0.14	4.10	4.10	0.00
HP1097-13	12.90	12.90	0.00	10.90	10.20	-6.42	68.30	67.90	-0.59	4.30	4.40	2.33
HP1097-14	11.70	11.90	1.71	10.70	10.40	-2.80	69.50	69.00	-0.72	4.10	4.10	0.00
HP1097-15	10.40	10.60	1.92	10.80	10.50	-2.78	70.80	70.70	-0.14	3.60	3.50	-2.78
HP1097-16	10.50	10.60	0.95	10.70	10.50	-1.87	70.20	70.00	-0.28	4.30	4.40	2.33
HP1097-20	10.80	11.10	2.78	10.80	10.30	-4.63	70.10	69.90	-0.29	4.30	4.40	2.33
HP1097-21	12.00	11.90	-0.83	10.60	10.40	-1.89	68.30	68.00	-0.44	4.80	4.70	-2.08
HP1097-23	12.30	12.30	0.00	11.00	10.50	-4.55	69.30	69.10	-0.29	4.00	4.00	0.00
LC-1	8.40	9.10	8.33	11.70	10.90	-6.84	71.60	71.20	-0.56	4.40	4.30	-2.27
Standard Error for Comparison	0.09			0.11			0.11			0.05		
Critical Value for Comparison	0.39			0.47			0.48			0.19		

	Ash %			**TCC**			**Pro-VA**		
Genotypes	Shade	Sundry	**% change**	Shade	Sundry	**% change**	Shade	Sundry	**% change**
HP1097-1	3.70	4.40	18.92	27.37	26.83	-1.95	10.49	8.91	-15.16
HP1097-2	3.70	3.80	2.70	17.37	16.07	-7.49	10.32	9.34	-9.50
HP1097-3	4.60	4.40	-4.35	16.37	12.10	-26.07	8.87	7.87	-11.27
HP1097-4	3.40	3.40	0.00	27.00	23.93	-11.36	8.81	7.8	-11.36
HP1097-5	2.90	3.40	17.24	20.67	16.67	-19.35	9.67	8.54	-11.69
HP1097-6	3.30	4.20	27.27	32.47	25.54	-21.33	7.91	9.7	-18.55
HP1097-7	3.70	3.70	0.00	18.67	15.93	-14.64	5.43	5.00	-7.92
HP1097-8	3.70	3.90	5.41	17.90	16.23	-9.31	6.78	6.00	-11.50
HP1097-10	3.40	4.90	44.12	28.33	27.00	-4.71	7.32	8.43	-13.16
HP1097-13	3.60	4.60	27.78	24.40	20.37	-16.53	8.76	8.65	-1.26
HP1097-14	4.00	4.60	15.00	20.40	14.40	-29.41	7.54	5.65	-25.07
HP1097-15	4.40	4.70	6.82	13.00	12.20	-6.15	4.56	4.40	-3.51
HP1097-16	4.30	4.50	4.65	22.50	24.90	10.67	6.54	7.43	13.61
HP1097-20	4.00	4.30	7.50	22.37	16.47	-26.38	8.54	8.32	-2.58
HP1097-21	4.30	5.00	16.28	26.20	23.73	-9.41	9.98	9.01	-9.72
HP1097-23	3.40	4.10	20.59	24.40	22.77	-6.69	10.32	9.89	-4.17
LC-1	3.90	4.50	15.38	13.67	11.67	-14.63	4.56	5.21	14.25
Standard Error for Comparison	0.0491			0.2078			0.23		
Critical Value for Comparison	0.204			0.8641			0.95		

Where, TCC: Total carotenoid contents (µg/g), Pro-VA: Pro-vitamin A carotenoids (µg/g)

Figure 3. (a) pigments of the cobs of provitamin A biofortified maize hybrids dried under covered conditions; (b, c, d) loss of pigments in cobs provitamin A biofortified maize hybrids dried under direct sun light.

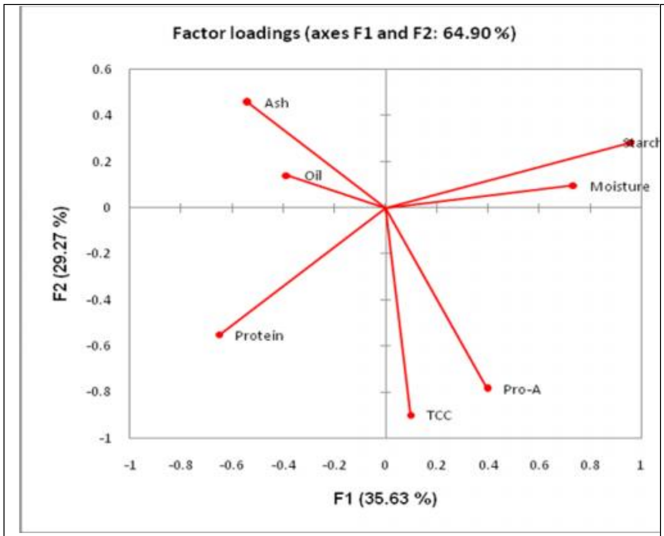

Figure 2. Correlation among different traits under shade drying conditions. Where, As, Oil, Starch, Protein and Moisture are in percentage, TCC: Total carotenoid contents (µg/g), Pro-VA: Pro-vitamin A carotenoids (µg/g)

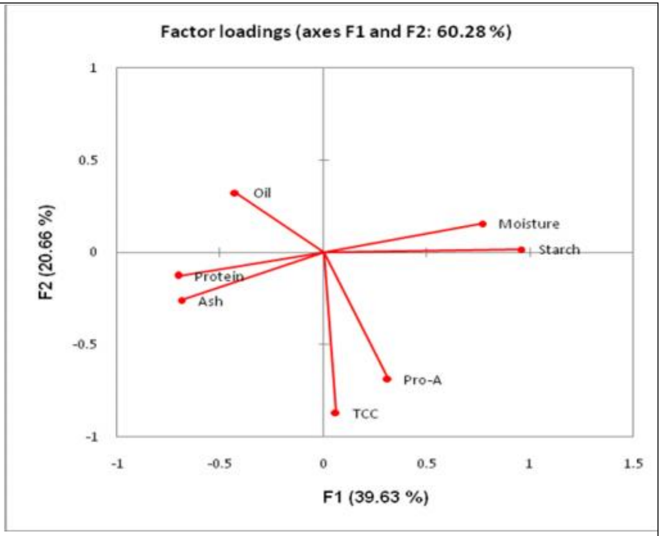

Figure 3. Correlation among different traits under sun drying conditions. Where, As, Oil, Starch, Protein and Moisture are in percentage, TCC: Total carotenoid contents (µg/g), Pro-VA: Pro-vitamin A carotenoids (µg/g)

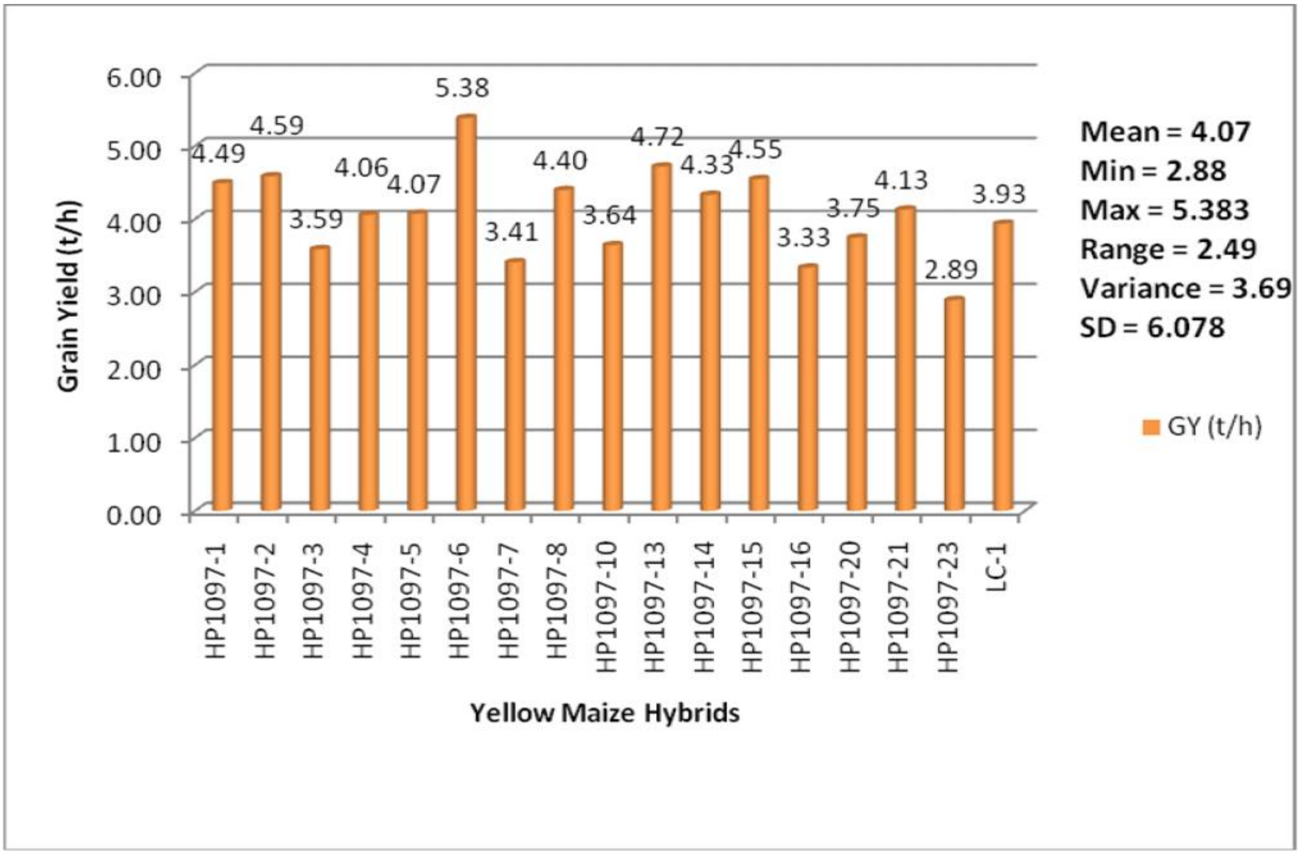

Figure 4: Mean grain yield (t/h) for studied maize hybrids. Where, Min: Minimum value, Max: Maximum value, SD: standard deviation. Grain yield was estimated for 10% moisture contents.

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