Response of Grain Yield and Yield Components of Various Maize Hybrids to Natural Weeds Population

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Abstract

In order to evaluate the weed competition effects on grain yield and yield components of corn, a split plot experiment was carried out based on Randomized Complete Block Design (RCBD) in three replications at Agricultural Research Station of Firoozabad, Fars, Iran in 2015. The main plots included two levels of weed infestations (W_0: weed free and W_1: weedy) and the sub-plots were consisted of 11 maize hybrids (AS160, AS41, AS42, AS66, AS42, AS51, AS54, AS55, AS62, AS63, AS66, AS72, AS73). The results of ANOVA showed that weeds resulted in reduction of leaf number, flag leaf area, ear length, number of kernels per row and grain yield. AS54 and AS160 hybrids had the highest and lowest grain yield under the weed-free condition, respectively, while, AS62 and AS55 hybrids had the highest and lowest grain yield under the weedy condition, respectively. According to the results of percent of grain yield loss, Ability to withstand competition (AWC) index and cluster analysis, AS62 and AS66 hybrids, which had high grain yield in both weed-free and weedy conditions, were the best genotypes in competition weeds and AS55 hybrid was the worst. Number of rows per ear and number of kernels per row were also the best traits to evaluate genotypes, competitiveness with weeds in weed-free and weedy conditions and to improve grain yield, respectively

Keywords: Cluster analysis, crop-weed competition, *Zea mays* L.

Introduction

Maize *(Zea mays* L.) is the third most important cereal crop after wheat and rice (Sureshkumari et al., 2015). In spite of its high potentialities, average corn yield in Iran is still very low as compared to other corn producing countries of the world. World production of maize is about 1005 million tones. Statistics illustrated that in Iran, it is grown on over 395 thousand hectares with total production of 1.3 million tons (FAO, 2015). It is well known that one of the problems in corn production is its yield loss by weeds competition (Kraehmer and Baur, 2013). It should be noted that competition on limited resources begins when plant density increases, or plants are of different sizes were (Auskalnis and Kadzys, 2006). Actually, competition between crop and weeds in farming systems is a very complex process made by a lot of parameters including water, nutrition and light. Light is the most important factor (Daugovish et al., 1999). Canopy characteristics such as leaf area duration and leaf area distribution are among factors that determine the intensity of competition between the crop and the weeds (Fessehaie and Lemma, 2003).

Crop competitiveness can be divided into two practical perspectives, such as: i) crop tolerance and ii) weed suppressive ability (Yim et al., 2009).

Crop tolerance can be defined as the ability of a crop to endure competitive stress from the presence of weeds without substantial loss of growth or yield. Whereas, weed suppressive ability of a crop is the ability to reduce weed growth and fecundity (Fateh et al., 2006). Competition between weeds and crops has been the subject of extensive research in agronomy (Cranmer et al., 2000). Although maize is a tall and strong plant, it is sensitive to weeds competition, and a yield loss of over 30% was reported due to weed infestation (Appleby and Valverde, 1989). Hence, weed management is one of the key parameters in most farming systems (Bàrberi, 2002). Moechnig et al. (2003) showed that grain yield, total dry matter, and seed row number per ear were affected by *Chenopodium album* L. population. Chaab et al. (2009) reported that weeds caused significant reduction in maize dry matter and leaf area index. Aryan-nia et al. (2011) showed that weeds removal had a significant effect on ear height, ear diameter, and cob weight. Yeganehpoor et al. (2015) demonstrated that yield and yield components of maize were significantly reduced by weed competition.

With a view to the above facts, the present study was aimed to recognize genotypes with high ability to compete with weeds and the effective traits on grain yield under weed-free and weedy conditions to improve maize breeding programs.

Materials and Methods

A field experiment was conducted at Agriculture Research Station of Firoozabad, Fars, Iran (28.35°N, 52.40°E and 1327 m above sea level) during 2015 growing season to evaluate the effect of natural weed population on grain yield and yield components of maize. The minimum and maximum cultivation temperatures were 21.1°C and 38.1°C, respectively. The annual precipitation was, on average, 550 mm and it had a relative humidity of 36%.

The studies were carried out as a split-plot experiment based on a Randomized Complete Block Design (RCBD) with three replications. The main plots included two levels of weed (W_0: weed-free, and W_1: weedy) and the sub-plots consisted of 11 maize hybrids (AS160, AS41, AS42, AS66, AS42, AS51, AS54, AS55, AS62, AS63, AS66, AS72, AS73) from Serbia country. Each experimental plot had a surface area of 20 m^2 with 4 m×5 m dimensions. Each plot consisted of seven planting rows with the length of six meters. In addition, the spacing between main plots was set to three meters, whereas the inter-plant distance on each row was 20 cm and the rows were 75 cm far from each other to achieve population density of 7 plant m^{-2}. Plough, two vertical disks, leveling, furrow and mound were used in plot building. The soil texture was loamy silt clay as well. Frequent soil analysis was performed for determination of fertilizer contents. Planting was accomplished after several ploughs. The plots were fertilized with 300 kg ha^{-1} of ammonium phosphate and 200 kg ha^{-1} N applied prior to planting plus an additional 200 kg ha^{-1} N top dressed at 7-leaf to 9-leaf stage.

All plots were irrigated normally throughout the season. In weed-free plots, weeds were removed completely by hand weeding during the growth period. Ten sample plants were taken from the middle part of each row and were labeled, and the border parts were left out. Then, the labeled plant samples were measured for the following traits: plant height (centimeters from the soil surface to the node below the tassel), leaf number, stem diameter (mm), ear leaf area (calculated by A=W×L×0.75 where A= area of ear leaf in cm^2, W= length of ear leaf in cm, and L= width of ear leaf in cm, flag leaf area (calculated by A=W×L×0.75 where A= area of flag leaf in cm^2, W= length of flag leaf in cm and L= width of flag leaf in cm), ear diameter, ear length (cm from the length of an unhusked ear from the butt to the tip), number of kernels per row, number of rows per ear, 100-grain weight and grain yield. Grain yield was measured at physiological maturity and yield was adjusted to 12.5% seed moisture content.

Normality test was carried out by Minitab software package (1998). Statistical calculations were performed using ANOVA appropriate with SAS software package (2001). MS-Excel software package (2003) was used to draw charts as well. Means comparison based on Duncan's multiple range test (DNMRT) was performed in SAS software package (2001). Relative yield loss (RYL) in weedy plots was calculated by the following equation:

Relative yield loss (%) = 100[(weed free yield – weedy yield)/weed free yield] (Haefele et al., 2004)

Ability to withstand competition (AWC) was calculated by the following equation (Jannink et al., 2000):

$$AWC = (\frac{Vi}{Vp}) \times 100$$

Where, Vi = grain yield of genotype *i* in weedy condition and Vp = grain yield of genotype *i* in weed free condition.

Hierarchical Cluster Analysis (HCA) of studied traits was carried out based on the Ward method by Minitab software package (1998).

Results and discussion

The results of ANOVA showed that weed effects were statistically significant for leaf number and flag leaf area ($P < 0.05$) and ear length, number of kernels per row, and grain yield ($P < 0.01$), indicating that these traits were influenced by weedy conditions whilst weed effect was not significant ($P > 0.05$) for plant height, stem diameter, ear leaf area, ear diameter, number of rows per ear, and 100-grain yield, indicating that these traits were not influenced by weedy condition (Table 1). Page (2009), also, reported similar results for leaf number.

Flag leaf area was affected by weeds so that was reduced by 44.05% under weedy condition. Therefore, flag leaf area was not suitable trait to evaluate genotypes for their ability to compete with weeds (Table 2). The number of rows per ear and 1,000 grain weight were decreased under weedy condition by 1.98 and 2.38%, respectively. Therefore, we can use these traits to evaluate the studied genotypes for their competitive ability with weeds. Grain yield was affected under weedy condition and it was reduced by 24.53% as compared to weed-free condition (Table 2). Rahmany and Nouraki (2015) also reported similar findings for the number of kernels per row and grain yield. The results indicated that the studied maize genotypes were significantly different in all traits, indicating the existence of genetic variability for the traits (Table 1). Aryannia et al. (2013) similarly revealed that genotype effects were highly significant for the number of rows per ear and grain yield.

Based on the results of means comparison, the highest leaf number was recorded to AS72, AS66 and AS54 hybrids in weed-free condition while AS63 hybrid had the highest leaf number in weedy condition, indicating that the studied genotypes had various responses to weed competition for this trait. The highest stem diameter belonged to AS 160 and AS73 hybrids in weed-free and weedy conditions (Table 3). AS63 hybrid had the highest ear leaf area and flag leaf area in weed-free condition. Given the fact that ear leaf area (Ali et al., 2015) and flag leaf area (Zeeshan et al., 2013) have positive direct effect on grain yield, AS63 hybrid seems to be suitable for weed-free condition.

The highest ear diameter and number of rows per ear was related to AS72 hybrid in weed free and weedy conditions. Therefore, AS72 hybrid can be used to improve these traits in both conditions (Table 3). AS160 hybrid also had the highest ear length in weed-free and weedy conditions. The highest number of kernels per row was devoted to AS160 hybrid in weed-free and AS62 hybrid in weedy conditions, indicating the importance of these genotypes to improve grain yield (Table 3). AS73 hybrid had the highest 100-grain weight in weed-free and weedy conditions. Therefore, this genotype can be recommended for this trait in both conditions. AS54 and AS72 hybrids had the highest grain yield in weed-free condition, whereas, AS62 hybrid had the highest grain yield in weedy condition (Table 3).

Weed × genotype interaction was statistically significant for leaf number, ear leaf area, number of kernels per row, and grain yield, indicating that genotypes responded to the conditions differently (Table 1). The highest and lowest leaf number was related to $W_0 \times G_{10}$ and

Table 1 Analysis of variance for 11 traits of 11 corn genotypes studied

S.O.V.	df	Mean of squares										
		Plant height	Leaf number	Stem diameter	Ear leaf area	Flag leaf area	Ear diameter	Ear length	Number of kernels per row	Number of rows per ear	100-grain weight	Grain yield
Block	2	6,502.18 *	3.63 *	2.51 ^{ns}	6,508.55 ^{ns}	6,092.7 ^{ns}	27.07 ^{ns}	38.04 **	52.02 *	1.32 ^{ns}	1.24 ^{ns}	25,462.1 **
Weed	1	2,16.14 ^{ns}	3.50 *	25.93 ^{ns}	2,081.18 ^{ns}	67,365.9 *	6.92 ^{ns}	200.9 **	717.35 **	1.75 ^{ns}	8.25 ^{ns}	11,8069.6 **
E (a)	2	213.90	0.06	5.32	9,158.93	3,154.15	39.15	0.30	1.80	0.57	1.60	164.25
Genotype	10	475.94 **	0.26 **	19.51 **	14,886.2 **	4,436.9 **	18.79 **	10.99 **	32.70 **	9.88 **	20.10 **	15,174.96 **
Weed × Genotype	10	111.74 ^{ns}	0.48 **	2.32 ^{ns}	14,75.38 *	4,46.91 ^{ns}	4.54 ^{ns}	0.77 ^{ns}	12.77 **	0.73 ^{ns}	0.34 ^{ns}	4,864.86 **
E (b)	40	74.80	0.09	1.75	769.94	376.08	3.04	0.62	1.57	0.88	2.42	696.38
%CV		3.70	2.22	6.47	4.90	17.15	3.48	3.69	3.15	5.86	5.28	8.92

Note: ns, * and **: Not significant, significant at $P < 0.05$ and $P < 0.01$, respectively.

$W_1 \times G_3$ interactions (14.22 and 12.99, respectively). $W_0 \times G_8$ and $W_1 \times G_6$ interaction resulted in the highest and lowest ear leaf area (644.83 cm^2 and 498.83 cm^2), respectively. The highest and lowest number of kernels per row belonged to $W_0 \times G_1$ and $W_1 \times G_6$ interactions (49.11 and 33.75), respectively. $W_0 \times G_5$, $W_0 \times G_{10}$, and $W_0 \times G_7$ interactions had the highest grain yield (420.63 g m^{-2}, 418.85 g m^{-2} and 387.56 g m^{-2}), respectively and $W_1 \times G_6$ interaction had the lowest grain yield (180.17 g m^{-2}) (Table 3).

Table 2 Means value for 11 traits of corn (*Zea mays* L.) under weed free (W_0) and weedy (W_1) conditions

Traits	W_0	W_1	% decrease
Plant height (cm)	232.12 ^{a}	235.74 ^{a}	-1.50
Leaf number	13.62 ^{a}	13.16 ^{b}	3.38
Stem diameter (mm)	21.12 ^{a}	19.87 ^{a}	5.92
Ear leaf area (cm^2)	571.45 ^{a}	560.22 ^{a}	1.97
Flag leaf area (cm^2)	145.05 ^{a}	81.16 ^{b}	44.05
Ear diameter (mm)	50.50 ^{a}	49.85 ^{a}	1.29
Ear length (cm)	23.04 ^{a}	19.55 ^{b}	15.15
Number of kernels per row	42.96 ^{a}	36.37 ^{b}	15.34
Number of rows per ear	16.14 ^{a}	15.82 ^{a}	1.98
100-grain weight (g)	29.80 ^{a}	29.09 ^{a}	2.38
Grain yield (g m^{-2})	337.29 ^{a}	254.55 ^{b}	24.53

Note: Means in each row, followed by similar letter(s) are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test

The dendrograms of cluster analysis using the Ward method were illustrated in Figures 1, 2, and 5. In the dendrograms (Figures 1 and 2), traits are presented on the horizontal axis and the correlation coefficient distances on the vertical. The studied traits were grouped into four clusters in weed-free and weedy conditions. Based on the results, 100-grain weight was located in the first cluster, grain yield, number of rows per ear, and leaf number were placed in the second cluster, flag leaf area, ear leaf area, ear diameter, and stem diameter were placed in the third cluster and other traits were grouped in the fourth cluster in weed-free condition, indicating that number of rows per ear and leaf number had the higher relationship with grain yield as compared to other traits (Figure 1).

AS54 and AS72 hybrids surpassed the nine other genotypes in grain yield in weed-free condition. The superiority of these genotypes was probably related to number of rows per ear and leaf number, respectively. AS62 hybrid produced high grain yield probably due to high number of rows per ear and leaf number in weed-free condition. AS160 hybrid had the lowest grain yield in weed-free condition. The inferiority of this genotype was probably related to the lowest number of rows per ear and leaf number. These results were confirmed by cluster analysis (Figure 1). The positive relationship between grain yield and number of rows per ear and leaf number were reported by Zeeshan et al. (2013) and Saidaiah et al. (2008), respectively.

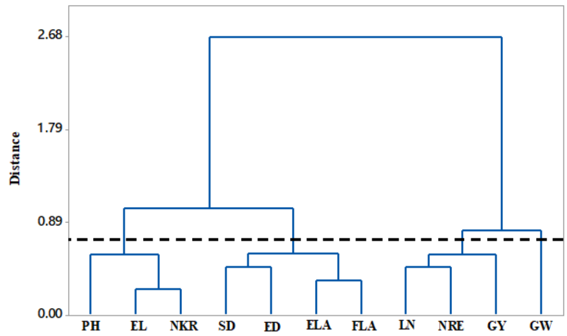

Figure 1 Cluster analysis of studied traits under weed free condition using Ward method

Note: PH: Plant height, LN: Leaf number, SD: Stem diameter, ELA: Ear leaf area, FLA: Flag leaf area, ED: Ear diameter, EL: Ear length, NKR: Number of kernels per row, NRE: Number of rows per ear, GW: 100-grain weight, GY: Grain yield

Based on cluster analysis of studied traits under weedy condition, number of rows per ear and ear diameter were grouped in the first cluster, 100-grain weight, flag leaf area, ear leaf area and stem diameter were placed in the second cluster, grain yield and number of kernels per row were placed in the third cluster, and other traits were grouped in the fourth cluster, indicating that the number of kernels per row had stronger relationship with grain yield than with other traits (Figure 2).

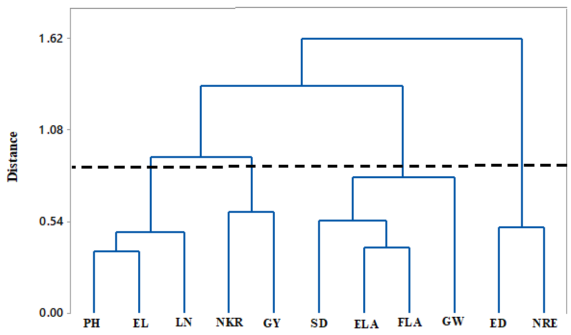

Figure 2 Cluster analysis of studied traits under weed free condition using Ward method

Note: PH: Plant height, LN: Leaf number, SD: Stem diameter, ELA: Ear leaf area, FLA: Flag leaf area, ED: Ear diameter, EL: Ear length, NKR: Number of kernels per row, NRE: Number of rows per ear, GW: 100-grain weight, GY: Grain yield

AS62 hybrid had the highest grain yield in weedy condition that it was probably due to the highest number of kernels per row (Table 3). On the other hand, AS55 hybrid had the lowest grain yield in weedy condition that it was probably due to the lowest number of kernels per row (Table 3). These results were confirmed by cluster analysis (Figure 2). These results are corroborated by the results of Shi et al. (2014).

The percent of grain yield loss suffered by maize hybrids infested with weeds was estimated as to be between 4.45% and 47.91% for AS160 and AS55 hybrids, respectively (Figure 3).

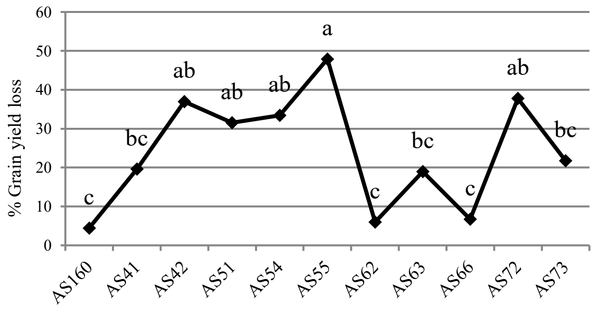

Figure 3 The percent of grain yield loss suffered by maize hybrids infested with weeds

AS62 and AS66 hybrids had the lowest percent of grain yield loss. The percent of AWC also ranged between 52.09 and 95.55 for AS55 and AS160, respectively (Figure 4).

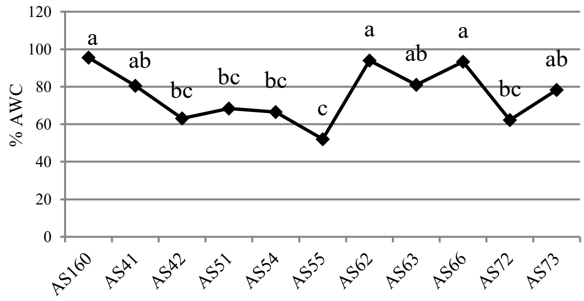

Figure 4 AWC percent of eleven maize genotypes to weed infestation

In the dendrogram (Figure 5), genotypes are presented on the horizontal axis and the Euclidean distances on the vertical.

Based on cluster analysis of maize genotypes for AWC, the genotypes were grouped into four clusters irrespective of the geographical divergence. Based on the results, AS160, AS62, and AS66 hybrids, which had the highest AWC, were grouped in the first cluster, AS41, AS63 and AS73 hybrids, which had high AWC, were grouped in the second cluster, AS42, AS51, AS54 and AS72 hybrids, which had moderate AWC, were grouped in the third cluster and AS55 hybrid, which had the lowest AWC, was grouped in the fourth cluster (Figure 5) that confirming above results.

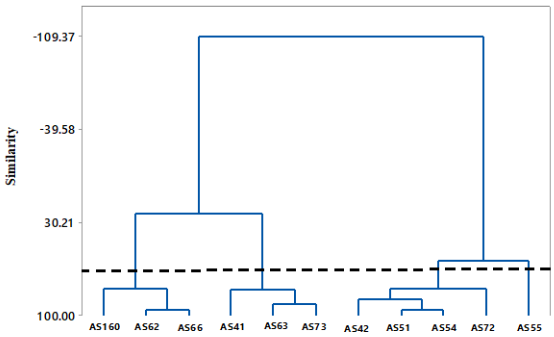

Figure 5 Cluster analysis of eleven corn genotypes for AWC using Ward method

Table 3 Effect of genotype on 11 traits in 11 corn hybrids under weed free and weedy conditions

Treatment		Plant height (cm)	Leaf number	Stem diameter (mm)	Ear leaf area (cm^2)	Flag leaf area (cm^2)	Ear diameter (mm)	Ear length (cm)	Number of kernels per row	Number of rows per ear	100-grain weight (g)	Grain yield (g m^{-2})
Genotype (weed-free plot)	AS160	233.38 ^{abc}	13.08 ^{e}	24.05 ^{a}	637.10 ^{a}	159.20 ^{bc}	51.08 ^{abc}	25.23 ^{a}	49.11 ^{a}	15.17 ^{def}	30.00 $^{a-e}$	228.75 ^{g}
	AS41	238.79 ^{ab}	13.42 ^{cd}	18.38 ^{e}	522.36 ^{b}	103.48 ^{d}	48.40 ^{c}	21.13 ^{d}	38.74 ^{e}	14.83 ^{ef}	30.00 $^{a-e}$	315.54 ^{de}
	AS42	218.46 ^{c}	13.25 ^{cde}	21.08 ^{bcd}	535.33 ^{b}	190.25 ^{a}	52.50 ^{ab}	21.44 ^{d}	43.92 ^{cd}	15.67 $^{c-f}$	28.67 ^{cde}	361.68 ^{bc}
	AS51	225.13 ^{bc}	13.50 ^{bcd}	19.36 ^{de}	496.74 ^{b}	114.22 ^{d}	50.46 ^{bc}	21.27 ^{d}	38.75 ^{g}	16.25 $^{b-e}$	29.00 $^{b-e}$	298.32 ^{ef}
	AS54	237.92 ^{ab}	14.08 ^{a}	19.75 ^{cde}	525.55 ^{b}	120.56 ^{d}	50.21 ^{bc}	23.25 ^{bc}	45.50 ^{bc}	17.58 ^{ab}	30.33 $^{a-d}$	420.63 ^{a}
	AS55	241.83 ^{a}	13.50 ^{bcd}	20.33 ^{cde}	536.81 ^{b}	130.55 ^{cd}	50.29 ^{bc}	23.96 ^{ab}	42.71 ^{de}	16.58 ^{bcd}	27.67 ^{de}	345.88 ^{bcd}
	AS62	223.42 ^{bc}	14.00 ^{ab}	20.81 ^{cd}	546.37 ^{b}	121.75 ^{d}	48.67 ^{c}	23.35 ^{bc}	43.57 ^{cd}	17.17 ^{abc}	31.33 ^{abc}	387.56 ^{ab}
	AS63	238.65 ^{ab}	13.83 ^{ab}	20.24 ^{cde}	644.83 ^{a}	196.80 ^{a}	49.42 ^{bc}	24.90 ^{a}	43.75 ^{cd}	14.17 ^{f}	27.00 ^{e}	331.67 ^{cde}
	AS66	234.46 ^{abc}	14.17 ^{a}	21.53 ^{bc}	596.08 ^{a}	133.80 ^{cd}	48.83 ^{c}	21.69 ^{d}	40.92 ^{ef}	15.92 ^{cde}	29.00 $^{b-e}$	348.97 ^{bcd}
	AS72	219.79 ^{c}	14.22 ^{a}	22.95 ^{ab}	616.70 ^{a}	155.61 ^{bc}	53.92 ^{a}	22.10 ^{cd}	39.54 ^{fg}	18.58 ^{a}	32.11 ^{ab}	418.85 ^{a}
	AS73	241.50 ^{a}	13.75 ^{abc}	23.88 ^{a}	628.14 ^{a}	169.38 ^{ab}	51.69 ^{abc}	25.15 ^{a}	46.06 ^{b}	15.67 $^{c-f}$	32.67 ^{a}	262.51 ^{fg}
Genotype (weedy plot)	AS160	231.67 ^{abc}	13.17 ^{ab}	22.60 ^{ab}	609.41 ^{ab}	89.31 ^{abc}	48.19 ^{cd}	21.54 ^{a}	38.63 ^{a}	14.67 ^{cd}	29.33 ^{bcd}	218.57 ^{def}
	AS41	243.96 ^{a}	13.08 ^{ab}	17.24 ^{d}	524.73 ^{cde}	49.72 ^{cd}	48.08 ^{cd}	18.10 ^{f}	35.00 ^{c}	15.25 ^{bcd}	29.33 ^{bcd}	253.77 ^{cde}
	AS42	219.79 ^{c}	12.99 ^{b}	18.43 ^{cd}	525.89 ^{cde}	115.73 ^{a}	52.06 ^{ab}	18.50 ^{def}	34.97 ^{c}	14.92 ^{cd}	28.33 ^{cde}	228.12 $^{c-f}$
	AS51	239.42 ^{ab}	13.08 ^{ab}	17.68 ^{d}	515.56 ^{de}	104.81 ^{cd}	50.33 ^{bc}	18.21 ^{ef}	35.67 ^{bc}	16.08 ^{bcd}	28.00 ^{cde}	204.28 ^{ef}
	AS54	235.58 ^{abc}	13.08 ^{ab}	17.79 ^{d}	500.39 ^{e}	43.58 ^{d}	48.23 ^{cd}	19.56 ^{cde}	38.22 ^{a}	15.75 ^{bcd}	29.67 ^{bcd}	280.03 ^{bc}
	AS55	226.71 ^{bc}	13.17 ^{ab}	19.67 ^{cd}	498.83 ^{e}	54.81 ^{cd}	49.85 ^{bc}	18.98 ^{def}	33.75 ^{c}	17.00 ^{b}	26.33 ^{e}	180.17 ^{f}
	AS62	234.17 $^{a-d}$	13.250 ^{ab}	21.25 ^{abc}	588.89 ^{b}	75.55 $^{a-d}$	50.98 ^{bc}	19.90 ^{bcd}	39.04 ^{a}	15.75 ^{bcd}	30.67 ^{abc}	364.47 ^{a}
	AS63	247.71 ^{a}	13.64 ^{a}	21.25 ^{abc}	611.97 ^{ab}	95.48 ^{ab}	46.15 ^{d}	20.69 ^{abc}	34.15 ^{c}	14.42 ^{d}	27.00 ^{de}	268.84 ^{cd}
	AS66	247.58 ^{a}	13.03 ^{b}	20.07 ^{bcd}	564.85 ^{bcd}	96.06 ^{ab}	50.38 ^{bc}	19.17 ^{def}	38.79 ^{a}	16.42 ^{bc}	27.33 ^{de}	325.59 ^{ab}
	AS72	218.21 ^{d}	13.17 ^{ab}	19.63 ^{cd}	648.88 ^{a}	100.25 ^{ab}	53.27 ^{a}	19.27 ^{def}	34.14 ^{c}	19.17 ^{a}	31.67 ^{ab}	260.66 ^{cd}
	AS73	248.33 ^{a}	13.08 ^{ab}	22.96 ^{a}	573.06 ^{bc}	111.30 ^{a}	49.81 ^{bc}	21.15 ^{ab}	37.67 ^{ab}	14.58 ^{cd}	32.33 ^{a}	205.36 ^{ef}

Note: Means in each column, followed by similar letter(s) are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test

Conclusion

Percent of grain yield loss, AWC index and cluster analysis demonstrated that AS62 and AS66 hybrids, which had high grain yield in weed-free and weedy conditions, were the best genotypes to compete with weeds and AS55 hybrid was the worst. Number of rows per ear and number of kernels per row had the highest positive direct influence on grain yield in weed-free and weedy conditions, respectively. Therefore, these traits were the best traits to evaluate genotypes, competitiveness with weeds to improve grain yield.

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