Effect of Harvesting Time on Grain Yield, Yield Components, and Some Qualitative Properties of Four Maize Hybrids

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Abstract

A field experiment was conducted to investigate the effect of harvest time on yield, yield components, and some qualitative properties of grain corn based on grain moisture content at Khorramabad Agricultural Research Station in 2010. The experimental design was a split plot based on RCB design with four replications. The investigated factors consisted of grain moisture, content at harvest time (20%, 30%, and 40%), and four maize hybrids (NS 640, Konsur 580, Jeta 600, and control SC 704). The results showed that the effect of grain moisture content at harvest time was significant on 400-grain weight, hectoliter weight, and grain electrical conductivity (EC) traits. The greatest electrical conductivity (551 µS/cm/g) was obtained for 40% grain moisture at harvest time. The highest 400-grain weight (103.01 g) and hectoliter weight (0.77 g/cm³) was obtained at the grain moisture content of 20%. The effect of hybrid was significant on all the investigated traits. NS 640 hybrid had the highest yield (8722.50 Kg/ha). Moreover, results suggested that suitable grain harvest time for the maize hybrids was after grain physiological maturity when grains reached 20% moisture content.

Keywords: Electrical conductivity; Grain moisture content; Grain quality; Hybrid

1. Introduction

Grain maize plays an important role in supplying food for human beings, livestock, and poultry, and also in industrial uses. It is exclusively used in agriculture due to the high energy supplement of maize grain (Kuchaki, 1994). In spite of the high importance of this crop, different qualitative traits of grain, such as low hectarliter and its tendency to become powdery during milling, have not been considered. Therefore, the production of a higher quality crop according to certain criteria is one of the main goals in maize production (Wych, 1988). The first step to increase crop quality is to realize the factors that influence the quality and its levels. Grain quality and quantity depend on various factors, such as soil, climate, and the time of cultural practices (McDonald and Copeland, 1997). Harvest time is very important in cultural operations and severely affects grain quality and quantity. The selection of a cultivar with high yield and low grain moisture at harvest time (before cold and autumn rainfall) is essential because the conditions for drying the crop are not suitable, and it causes low demands of poultry and livestock industry for the harvested crop (Rafiee et al., 2002). Grain moisture content affects the cost of the drying process after harvest (Nielson, 2009). Higher grain moisture content during storage produces more heat in the grain due to high grain
respiration, and this causes grain deterioration and the reduction of storage period (Hellevang, 2009; Nielson, 2009). Peplinski et al. (1994) reported when maize crop was harvested early, the quality and quantity was reduced, especially for the hectoliter of crop. The toughness of grain at this state is lower. More air humidity was absorbed resulting in more fungi growth. They stated these grains are broken in the dryer during the drying process. Maier and Parsons (1996) reported that harvesting maize crop at dough stage, when the grain moisture content is 60%, reduces grain yield and hectoliter weight, whereas harvest at dent stage, when grain moisture content is 55%, still reduces hectoliter weight. Using new foreign cultivars with different growth periods can be one of the strategies to achieve self-sufficiency for maize in the country in a quicker time (Khajehpur and Karimi, 1988). Therefore, this research aimed to investigate the effect of harvest time on different crop traits and crop quality based on grain moisture content and maize hybrids.

2. Materials and Methods

The field experiments were carried out at an agricultural research station in Khorramabad, Iran in 2010. The experiment was arranged in a split plot based on randomized complete block design with four replications. The factors consisted of four maize hybrids (NS 640, Konsur 580, Jeta 670, and SC 704 as control) and three harvest times (20, 30, and 40 percent grain moisture content). The maize grains were sown in the form of hill planting (3 to 4 grains in each whole, at 5 cm deep) with 18 cm distance between sowing hills on rows and the rows spaced 75 cm apart. The plants were thinned to one plant in four- to five-leaf stages. Each maize hybrid was planted in 12 rows. The chemical fertilizers, including NPK based on the results of soil test, were applied as 200 kg ha$^{-1}$ nitrogen in the form of urea, 150 kg ha$^{-1}$ phosphorous in the form of super phosphate triple, and 50 kg ha$^{-1}$ potash in the form of potassium sulfate. At harvest time, grain yield based on 14% moisture content, other yield components, and some morphological traits were measured. At the end, two middle rows were harvested by considering 50 cm from two sides. Grain weight was randomly measured based on 400-grain weight using a balance with 0.001 accuracy. The number of rows per ear and number of grains per row were randomly measured using ten ears. Hectoliter weight was measured by dropping the grains in a 500 cm$^3$ dish, removing the extra grains and weighing the sample, and dividing by the volume of the dish (Deshpande et al., 1993).

$$P_b = \frac{M_b}{V_b}$$

Where $M_b$ is the sample mass, $V_b$ is the dish volume, and $P_b$ is hectoliter weight.

Electrical conductivity was determined by the method of Free (2004). Briefly, 250 ml distilled water was added to a 500 cm$^3$ dish with a grain sample. The grain in distilled water was incubated at 20$^\circ$C for 24 hrs. After 24 hrs, two 50-grain samples were placed in covered dishes and incubated for 24 hrs. Electrical conductivity of grain samples was measured by EC meter (model, JENWAY 4010) using the following formula:

$$EC = \frac{W_1 + W_2}{2W_1 + 2W_2}$$

Where $EC_1$ and $EC_2$ is EC for grain sample 1 and 2, and $W_1$ and $W_2$ are the weight of grain sample 1 and 2, respectively.

The data was tested for normality using Minitab version 12. The data was analyzed using the ANOVA procedure of the SAS. The means were separated using Least Significant Differences (LSD) in MSTAT-C at the 5% probability level.

3. Results and Discussion

3.1 Grain Yield

The results showed that there were highly significant differences ($p<0.01$) between cultivars for grain yield (Table 1). The highest grain yield (8722 kg ha$^{-1}$) was achieved for hybrid NS 640 (Table 2). There was no significance difference ($p>0.05$) between harvest times based on grain moisture content (Table 1). Maier and Parson (1996) reported that grain yield reduced when maize crop was harvested at dough stage with 60% of grain moisture content. Among yield components, grain weight influenced more because it determines the period of grain filling.
Table 1

The variance analysis of yield, yield components and some qualitative properties

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Df</th>
<th>Grain yield</th>
<th>400-grain weight</th>
<th>Number of rows per ear</th>
<th>Number of grains per row</th>
<th>Hectoliter weight</th>
<th>Grain electrical conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>3</td>
<td>70994.65 ns</td>
<td>41.48&quot;</td>
<td>0.30 ns</td>
<td>11.68 ns</td>
<td>0.001 ns</td>
<td>0.22 ns</td>
</tr>
<tr>
<td>Hybrid</td>
<td>3</td>
<td>706621.09 **</td>
<td>149.19&quot;</td>
<td>2.60 &quot;</td>
<td>42.35 &quot;</td>
<td>0.006&quot;</td>
<td>2.90 &quot;</td>
</tr>
<tr>
<td>Erorr1</td>
<td>9</td>
<td>59430.22</td>
<td>3.31</td>
<td>0.27</td>
<td>9.31</td>
<td>0.001</td>
<td>0.49</td>
</tr>
<tr>
<td>Grain moisture</td>
<td>2</td>
<td>7154.79 ns</td>
<td>10.25&quot;</td>
<td>0.25 ns</td>
<td>0.22 ns</td>
<td>0.001 &quot;</td>
<td>1.03 &quot;</td>
</tr>
<tr>
<td>Hybrid *Grain moisture</td>
<td>6</td>
<td>2261.42 ns</td>
<td>1.85 ns</td>
<td>0.12 ns</td>
<td>0.80 ns</td>
<td>0.0001 ns</td>
<td>0.33 ns</td>
</tr>
<tr>
<td>Erorr2</td>
<td>24</td>
<td>9191.55</td>
<td>0.87</td>
<td>0.43</td>
<td>1.45</td>
<td>0.0001</td>
<td>0.21</td>
</tr>
<tr>
<td>c .v</td>
<td></td>
<td>1.12</td>
<td>0.91</td>
<td>4.31</td>
<td>3.18</td>
<td>1.83</td>
<td>8.81</td>
</tr>
</tbody>
</table>

*,**, and ns show significant difference at probability of %5, %1 and no significant difference, respectively

Table 2

The mean comparisons of yield, yield components and some qualitative properties in various hybrids of maize

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Grain yield (Kg/ha)</th>
<th>400-grains weight (g)</th>
<th>Number of rows per ear</th>
<th>Number of grains per row</th>
<th>Hectoliter weight (g/cm³)</th>
<th>Grain electrical conductivity (µs/cm/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeta 600</td>
<td>8580.07 a</td>
<td>106.63 a</td>
<td>14.75 b</td>
<td>36.79 c</td>
<td>0.77 a</td>
<td>483 a</td>
</tr>
<tr>
<td>Sc704</td>
<td>8629.04 a</td>
<td>103 a</td>
<td>15.46 a</td>
<td>38.50 b</td>
<td>0.77 a</td>
<td>505 a</td>
</tr>
<tr>
<td>Ns 640</td>
<td>8722.50 a</td>
<td>102.46 b</td>
<td>15.67 a</td>
<td>40.08 a</td>
<td>0.78 b</td>
<td>514 a</td>
</tr>
<tr>
<td>Konsur 580</td>
<td>8173.15 c</td>
<td>98.03 c</td>
<td>14.79 b</td>
<td>35.83 c</td>
<td>0.73 b</td>
<td>596 a</td>
</tr>
</tbody>
</table>

The averages with at least one common letter, based on LSD test, showed no significant difference.

Table 3

The mean comparisons of yield, yield components and some qualitative properties in various grain moisture content at harvest

<table>
<thead>
<tr>
<th>Grain Moisture (%)</th>
<th>Grain yield (Kg/ha)</th>
<th>400-grains weight (g)</th>
<th>Number of rows per ear</th>
<th>Number of grains per row</th>
<th>Hectoliter weight (g/cm³)</th>
<th>Grain electrical conductivity (µs/cm/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>8546.61 a</td>
<td>103.01 a</td>
<td>15.28 a</td>
<td>37.75b</td>
<td>0.77 a</td>
<td>501 b</td>
</tr>
<tr>
<td>30</td>
<td>8527.58 a</td>
<td>102.97 a</td>
<td>15.19 a</td>
<td>37.72 a</td>
<td>0.76 a</td>
<td>522 ab</td>
</tr>
<tr>
<td>40</td>
<td>8504.38 a</td>
<td>101.60 b</td>
<td>15.03a</td>
<td>37.94 a</td>
<td>0.75 b</td>
<td>551 a</td>
</tr>
</tbody>
</table>

The averages with at least one common letter, based on LSD test, showed no significant difference.
3.2 Row Number per Ear and the Number of Grain per Row

The results of ANOVA showed that harvest time had no significant effect on \( p > 0.05 \) the number of rows per ear and the number of grains per row (Table 1). These results were expectable and logical because the number of rows and grain number per row are formed before the grain filling stage. The harvest time does not affect these two yield components. Moreover, these two yield components are more influenced by genetic structure than environmental factors (Fereiduni et al., 2011). There were significant differences \( p < 0.01 \) among hybrids for these two traits (Table 1). Mean comparisons showed that the highest number of rows per ear (15.67) and grain number per row (40.08) were produced by hybrid NS 640 (Table 2).

3.3 400-Grain Weight

There was significant difference \( p < 0.01 \) between hybrids for grain weight (Table 1). The greatest 400-grain weight was achieved for hybrid Jeta 600 (Table 2). The effect of grain moisture content at harvest time was highly significant \( p < 0.01 \) for grain weight. The mean comparisons (Table 2) showed that the highest 400-grain weight (103.01g) obtained when the harvest time was done at the moisture content was 20\% (Table 3 and Fig. 1). Sroller et al. (1984) showed that a delay in harvesting increased real grain weight and its dry matter by periodic sampling and laboratory analysis.

3.4 Hectoliter Weight

From the analysis of variance of the data, the results showed that hectoliter weight was significantly different among hybrids (Table 1). Mean comparisons showed that the highest hectoliter weight \( (0.78 \text{ g m}^{-3}) \) belonged to NS 640 hybrid (Table, 2). The effect of grain moisture content on hectoliter weight was also highly significant \( p < 0.01 \) (Table 1). Mean comparisons showed that hectoliter weight was the highest \( (0.77 \text{ g m}^{-3}) \) when harvest was done at 20\% grain moisture content (Table 3 and Fig. 2). Hectoliter weight is reduced with grain moisture content increasing. Choukan (2008) reported that the lowest hectoliter weight was achieved at grain dough stage \( (0.75 \text{ g m}^{-3}) \) and at the end of dent stage \( (0.76 \text{ g m}^{-3}) \), and the highest value was at two weeks after physiological maturity with a hectoliter weight of \( 0.78 \text{ g m}^{-3} \). Szymańek (2009) stated that by delaying harvest, hectoliter weight increased from 585.51 kg m\(^{-3}\) to 609.11 kg m\(^{-3}\) in sweet corn.

![Figure 1](image1.png)

**Figure 1:** The effects of grain moisture content at harvest time on 400-grains weight of corn

![Figure 2](image2.png)

**Figure 2:** The effects of grain moisture content at harvest time on hectoliter weight of corn

3.5 Grain Electrical Conductivity

Grain electrical conductivity (EC) is one of the criterions to measure the quality of grain. Mature grains leak out less materials due to the formation of essential structural compounds. The results showed that this trait was affected by harvest time (Table 1). Mean comparisons showed significant differences between harvest times (Table, 3).
a reduction in Grain EC with postponement in harvesting. Among hybrids there were significant \( p<0.05 \) differences as well. Hybrid Konsur 580 showed the highest grain EC with 596 \( \mu S/cm/g \).

### 3.6 Correlation between Traits

Correlation coefficients were presented in Table 4. It showed significant positive correlation between grain yield and 400-grain weight, number of rows per ear, number of grains per row, and hectoliter weight. Grain yield showed significant and negative correlation with grain EC (Table 4). Sharma et al. (1984) have also reported positive and significant correlation between grain yield with number of grain per ear, ear weight, and 1000-grain weight. There was also a significant and positive correlation between grain yield and hectoliter weight and a negative and significant correlation between these two traits (Table 4). Vaezy et al. (1998) reported a positive correlation between grain yield, grain weight, and grain depth. A positive and significant correlation was also reported between grain yield and ear length and number of grains per row in a study by Masji Bahosh et al. (2010). Hectoliter weight showed a significant and positive correlation with all traits except grain EC (Table 4).

### Figure 3

The effects of grain moisture content at harvest time on grain electrical conductivity of corn

The highest EC (551 \( \mu S/cm/g \)) was obtained at 40% grain moisture content, and the lowest EC (501 \( \mu S/cm/g \)) was observed for harvest at 20% (Fig. 3). Higher EC was found at 40% grain moisture content because grain is not mature yet, the cell membrane is not fully informed, and grain cover is hard enough, so there is more material leakage. Overall, grain EC is reduced by delaying in harvest. Durrant and Loads (1990) also reported

### Table 4

Correlation coefficients among traits of corn hybrids

<table>
<thead>
<tr>
<th>Traits</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Grain yield</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 400-grains weight</td>
<td>0.708**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Number of rows per ear</td>
<td>0.666*</td>
<td>0.076( ns )</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Number of grains per row</td>
<td>**0.826</td>
<td>0.229( ns )</td>
<td>**0.855</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Hectoliter weight</td>
<td>**0.929</td>
<td>**0.780</td>
<td>0.597</td>
<td>0.677</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6 Grain electrical conductivity</td>
<td>**-0.760</td>
<td>**-0.884</td>
<td>( ns ) 0.309</td>
<td>( ns ) -0.435</td>
<td>**-0.850</td>
<td>1</td>
</tr>
</tbody>
</table>

* ** and \( ns \) show significant difference at probability of %5, %1 and no significant difference, respectively.
4. Conclusion

According to the results from this research, hybrid NS 640 has priority over other hybrids for the grain yield under this climate condition. The best time for harvest of the maize crop is when grain moisture content is 20% for higher quality grains. At this grain moisture content, the highest hectar lite weight and the lowest grain EC was achieved. Therefore, the selection of an appropriate hybrid with ideal grain moisture content is the strategy to improve maize crop quality.

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