Effect of Plant Density on Silage Yield and Quality of some Maize 
(Zea mays L.) Hybrids

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ABSTRACT
This experiment was conducted at Grower Farm in Al-Maamorah district, El-Ghafara, Tripoli, Libya, during 2020 summer season to study effect of four maize hybrids (SC 10, SC 176, TC 310 and TC 360) as main plots and three maize plant densities, i.e. 166667, 83333 and 55555 plants/ ha as sub plots in a split plot design with three replicates on silage yield and quality. Results showed that SC 10 had the tallest plants (183.03 and 210.93 cm) and stalk diameters (21.08 and 24.46 mm) at 55 and 90 DAS, leaf/ stem ratio (59.06%), number of ears/ plant (1.21) and total dry forage yield (17.059 t/ ha) at 90 DAS. However, single crosses studied were significantly surpassed in leaf area index, number of leaves/ plant and total dry forage yield at 55 DAS, besides protein yield.

The highest plant density (166667 plants/ ha) produced maximum plant height and total dry forage yield at 55 and 90 DAS, maximum L.A.I. at 55 DAS. Conversely, the lowest plant density (55555 plants/ ha) produced thicker stalks and highest plant dry weight at 55 and 90 DAS and highest leaf/ stem ratio, protein yield and number of ears/ plant. Interaction between the two factors studied pointed out that sowing SC 10 at 166667 plants/ ha produced the tallest plants and highest total dry forage yield at 55 and 90 DAS, and LAI at 55 DAS. However, sowing the same hybrid at the lowest plant density showed thicker stalks at 55 and 90 DAS, number of leaves and ears/ plant.

Keywords: maize, plant density, hybrids, silage, yield, quality.

INTRODUCTION
Corn (Zea mays L.) is a very important cereal crop in the world and Egypt. It is used as food, feed and industrial crop. Nowadays, it becomes a major source for silage for feeding cattle during the summer season in Egypt, because maize produced high yield and dry matter per unit area, high energy content and quality of its biomass for animal production (Roth and Undersander, 1995 and Mandic et al., 2015).

Deinum and Struik (1989) reported that digestion of silage transformed to volatile fatty acids, that considered essential for milk production. Maize breeders aimed to increase fresh and dry matter of silage maize that contain higher percentage of ears and good quality (stalks quality and ability for digestion). Besides the best maize genotypes, cultural practices as plant density is considered for maximizing corn production per unit area. High plant density of hybrid corn significantly increased silage yield without decreasing of its nutritional value (Ferreira et al., 2014 and Al-Naggar et al., 2016). On the other hand, Hunter (1986) and Cox (1997) concluded that the suitable plant density of silage plants is 10- 20 % higher than cultivated corn for grain yield. The objective of this study is evaluation of productivity and quality of silage resulted from cultivation some maize hybrids under different plant density.

MATERIALS AND METHODS
A field experiment in 2020 summer season was carried out at Grower Farm located in Al-Maamorah district, El-Ghafara, Tripoli, Libya, in split plot design with three replications to study plant density effect on silage yield and quality of some maize (Zea mays L.) hybrids. The main plots occupied by four maize hybrids, i.e. white and yellow single crosses (SC 10 and SC 176) and white and yellow triple crosses (TC 310 and TS 360), respectively. However, three plant densities, i.e. D1 (166667), D2 (83333) and D3 (55555) plants/ ha, were randomly assigned as sub plots. Sowing date was 15 July. Sub-plot area was 9 m² (five ridges each 3 m length and 0.6 m width). Manually planting was done on one side of the ridge with two kernels/ hill. Distances between hills were 10, 20 and 30 cm (166667, 83333 and 55555 plants/ ha) for D1 and D2 and D3 densities, respectively. At 21 days (DAS), plants were thinned to one plant/ hill. Nitrogen fertilization was applied at the rate of (140 kg N/ ha) as ammonium nitrate (33.3% N). Other cultural practices for maize production were carried out as recommended.

Plant samples were harvested from a one meter length from the third ridge in each sub-plot by cutting 10 cm above the soil surface at 55 and 90 DAS to determine plant height (cm), stalk diameter (mm), leaf area index (L.A.I), plant dry weight (g) and total dry forage yield (t/ ha) which calculated by multiplying plant dry weight by plant density. At harvest (90 DAS) number of leaves/ plant, leaf/ stem ratio (%) and protein yield (t/ ha) were determined. Protein yield (t/ ha) calculated by multiplying total dry forage yield (t/ ha) by crude protein content (%), where crude protein...
content (%) was determined by multiplying nitrogen content (%) × 6.25 according to (A.O.A.C., 1990).

Data were subjected and statically analyzed according Steel and Torrie (1980) and comparisons between means were carried out using least significant difference method (L.S.D) at 0.05 level of probability.

RESULTS AND DISCUSSION

I- Hybrids effect:

Plant characters and total dry forage and protein yields of maize as affected by maize hybrids, plant density and their interactions are presented in (Tables 1 and 2). Results in Table (1) showed that the studied traits were significantly affected by the studied four maize hybrids, except leaf area index (LAI) at 55 days after sowing (DAS) and plant dry weight at 55 and 90 DAS; plant density, except LAI at 90 (DAS) Interaction between maize hybrids × plant density, also had significant effect on all the characters under study, except (LAI) at 55 DAS and protein yield.

Concerning the differences between the four maize hybrids studied, obtained results showed that single crosses, especially SC 10 generally produced the highest values for the studied traits. That could be due to higher hybrid vigor (heterosis) in the first generation (F₁) in single crosses than triple crosses of maize.

Regarding the studied traits, SC 10 had the tallest maize plants (183.03 cm) at 55 DAS, highest stalk diameters (21.08 and 24.46 mm) at 55 and 90 DAS, respectively. Single cross 10, also surpassed the other maize genotypes studied for leaf/ stem ratio (59.06 %), number of ears/ plant (1.21) and total dry forage yield at 90 DAS (17.059 ton/ ha). On the other hand, single crosses (SC 10 and SC 176) had taller plants (210.93 and 209.72 cm) at 90 DAS, higher number of leaves/ plant (15.59 and 15.31), highest LAI (6.39 and 6.28) at 90 DAS, total dry forage yield (13.708 and 13.508 ton/ ha) at 55 DAS and protein yield (1.14 and 1.17 ton/ ha), respectively. These findings are in consistent with those reported by El-Metwally et al. (2011), El-Shahed et al. (2013) and Hegab et al. (2019) for plant height, El-Shahed et al. (2013) for stalk diameter, Awadalla and Morsy (2016), El-Hosary et al. (2019) and Hegab et al. (2019) for number of leaves/ plant, El-Metwally et al. (2011), El-Shahed et al. (2013) and Hegab et al. (2019) for leaf area index. The same trend of plant characters have been reported by Nazli et al. (2019) for leaf/ stem ratio and El-Metwally et al. (2011) for number of ears/ plant. On the other hand, Gaile (2008), Lynch et al. (2012) and El-Hosary et al. (2019) reported that maize hybrids showed significant differences in total dry forage yield and protein yield.

II- Plant density effect:

Considering plant density effect, results presented in Table (1) indicated that the highest maize plant density (166667 plants/ ha) produced the tallest plants (184.54 and 212.40 cm), total dry forage yield (13.927 and 17.448 t/ ha) at 55 and 90 DAS and leaf area index (3.65) at 55 DAS. Conversely, the lowest plant density (55555 plants/ ha) produced thicker stalk diameter (21.12 and 24.34 mm), heaviest plant dry weight (224.10 and 272.34 g) at 55 and 90 DAS, highest number of leaves/ plant (15.83), highest leaf/ stem ratio (60.62 %), highest number of ears/ plant (1.22) and highest protein yield (1.22 t/ ha). Higher competition between maize plants in higher plant density on light could be accelerated plant height and consequently increased plant height as a result of increase internode length and that led to decrease number of leaves/plant, stalk diameter, plant dry weight, leaf/ stem ratio, number of ears/plant and protein yield. However, increasing number of plants per unit area (high plant density) increased leaf area index and total dry forage yield. These results are in line with those obtained by El-Hosary et al. (2019), Fromme et al. (2019) and Li et al. (2019) for plant height, Mandic et al. (2015) and Fromme et al. (2019) for stalk diameter, Kumar et al. (2016) and El-Hosary et al. (2019) for number of leaves/ plant, El-Sobky and Al-Naggar (2016) and Rahouma (2018) for number of ears/ plant, Karasahin (2014) for plant dry weight, El-Shahed et al. (2013), Rahuma (2018) and El-Hosary et al. (2019) for leaf area index, Ferreira et al. (2014), Haddadi and Mohseni (2016) and Opoku (2017) for total forage yield and El-Hosary et al. (2019) for protein yield.

III- Hybrid × plant density interactions effect:

Results presented in Table (2) revealed that interactions between the studied maize hybrids and plant density had significant effects on all studied traits, except leaf area index at (55 DAS) and protein yield per hectare. That means the four maize hybrids were differently responded to plant densities studied. With respect plant height trait at 55 and 90 DAS, decreasing plant density significantly decreased plant height in all the studied hybrids and SC 10 produced the tallest plants (190.51 and 220.62 cm) at 55 and 90 DAS, respectively, under the highest plant density (166667 plants/ ha). The same trend obtained for leaf area index at 90 (DAS), where SC 10 realized the highest LAI (7.22), total dry forage yield, also took similar trend, where lax plant population, generally produced the lowest total dry forage yield, however SC 10 produced the highest total dry forage yield (15.10 and 18.97 t/ ha) at 55 and 90 (DAS) when sown at 166667 plants/ ha, also sowing SC 176 at 166667 plants/ ha produced
Table 1. Means of maize plant characters, total dry forage and protein yields as affected by hybrids, plant density and their interactions in 2020 season

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height (cm)</th>
<th>Stalk diameter (mm)</th>
<th>Number of leaves/plant</th>
<th>L.A.I.</th>
<th>Plant dry weight (g)</th>
<th>Leaf/stem ratio</th>
<th>Number of ears/plant</th>
<th>Total dry forage yield (t/ha)</th>
<th>Protein yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>55 DAS</td>
<td>90 DAS</td>
<td>55 DAS</td>
<td>90 DAS</td>
<td>55 DAS</td>
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<td>55 DAS</td>
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<td></td>
</tr>
<tr>
<td>SC 10</td>
<td>183.03</td>
<td>^a^</td>
<td>210.93</td>
<td>^a^</td>
<td>21.08</td>
<td>^a^</td>
<td>24.46</td>
<td>^a^</td>
<td>15.59</td>
</tr>
<tr>
<td>SC 176</td>
<td>179.96</td>
<td>^ab^</td>
<td>209.72</td>
<td>^a^</td>
<td>20.65</td>
<td>^b^</td>
<td>22.55</td>
<td>^b^</td>
<td>15.31</td>
</tr>
<tr>
<td>TC 310</td>
<td>168.35</td>
<td>^b^</td>
<td>196.54</td>
<td>^ab^</td>
<td>19.64</td>
<td>^b^</td>
<td>21.56</td>
<td>^b^</td>
<td>13.66</td>
</tr>
<tr>
<td>TC 360</td>
<td>166.25</td>
<td>^b^</td>
<td>182.60</td>
<td>^b^</td>
<td>18.74</td>
<td>^b^</td>
<td>22.23</td>
<td>^b^</td>
<td>13.30</td>
</tr>
<tr>
<td>L.S.D0.05</td>
<td>13.81</td>
<td>21.26</td>
<td>1.23</td>
<td>1.89</td>
<td>0.94</td>
<td>n.s</td>
<td>1.08</td>
<td>n.s</td>
<td>n.s</td>
</tr>
<tr>
<td>Plant density</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1</td>
<td>184.54</td>
<td>^a^</td>
<td>212.40</td>
<td>^a^</td>
<td>19.09</td>
<td>^b^</td>
<td>21.17</td>
<td>^c^</td>
<td>13.35</td>
</tr>
<tr>
<td>D2</td>
<td>173.45</td>
<td>^ab^</td>
<td>198.79</td>
<td>^ab^</td>
<td>19.88</td>
<td>^b^</td>
<td>22.59</td>
<td>^b^</td>
<td>14.21</td>
</tr>
<tr>
<td>D3</td>
<td>165.20</td>
<td>^b^</td>
<td>188.65</td>
<td>^b^</td>
<td>21.12</td>
<td>^a^</td>
<td>24.34</td>
<td>^a^</td>
<td>15.83</td>
</tr>
<tr>
<td>L.S.D0.05</td>
<td>11.34</td>
<td>16.70</td>
<td>0.95</td>
<td>1.08</td>
<td>0.67</td>
<td>n.s</td>
<td>0.52</td>
<td>n.s</td>
<td>24.74</td>
</tr>
</tbody>
</table>

D1: 166667; D2: 83333; D3: 55555 plants/ha

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.
Table 2. Means of maize plant characters, total dry forage and protein yields as affected by interaction between hybrids and plant density in 2020 season

<table>
<thead>
<tr>
<th>Maize hybrid</th>
<th>Plant density</th>
<th>Plant height (cm)</th>
<th>Stalk diameter (mm)</th>
<th>Number of leaves/plant</th>
<th>L.A.I.</th>
<th>Plant dry weight (g)</th>
<th>Leaf/stem ratio</th>
<th>Number of ears/ plant</th>
<th>Total dry forage yield (t/ha)</th>
<th>Protein yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>D1</td>
<td>190.51 a</td>
<td>220.62 a</td>
<td>20.12 ab</td>
<td>22.98 ab</td>
<td>14.65 bc</td>
<td>3.92 a</td>
<td>7.22 a</td>
<td>90.20 c</td>
<td>118.37 c</td>
</tr>
<tr>
<td>D2</td>
<td>D1</td>
<td>182.17 ab</td>
<td>210.86 ab</td>
<td>20.98 ab</td>
<td>24.27 ab</td>
<td>15.10 bc</td>
<td>3.40 a</td>
<td>6.02 ab</td>
<td>166.32 b</td>
<td>195.84 b</td>
</tr>
<tr>
<td>D3</td>
<td>D1</td>
<td>176.43 ab</td>
<td>201.31 b</td>
<td>22.14 a</td>
<td>26.15 a</td>
<td>17.03 a</td>
<td>2.86 a</td>
<td>5.94 ab</td>
<td>225.36 a</td>
<td>289.08 a</td>
</tr>
<tr>
<td>D1</td>
<td>D1</td>
<td>184.96 ab</td>
<td>220.17 ab</td>
<td>19.89 ab</td>
<td>20.16 b</td>
<td>14.39 c</td>
<td>3.67 a</td>
<td>6.83 ab</td>
<td>84.00 c</td>
<td>109.87 c</td>
</tr>
<tr>
<td>D2</td>
<td>D1</td>
<td>180.35 ab</td>
<td>208.49 ab</td>
<td>20.61 ab</td>
<td>22.67 b</td>
<td>15.56 b</td>
<td>3.90 a</td>
<td>6.24 ab</td>
<td>162.84 b</td>
<td>181.20 b</td>
</tr>
<tr>
<td>D3</td>
<td>D1</td>
<td>174.59 b</td>
<td>200.50 b</td>
<td>21.47 ab</td>
<td>24.84 ab</td>
<td>16.00 ab</td>
<td>3.10 a</td>
<td>5.79 b</td>
<td>235.98 a</td>
<td>266.76 a</td>
</tr>
<tr>
<td>D1</td>
<td>D1</td>
<td>180.62 ab</td>
<td>208.34 ab</td>
<td>18.44 b</td>
<td>20.17 b</td>
<td>12.11 d</td>
<td>3.67 a</td>
<td>4.88 bc</td>
<td>82.91 a</td>
<td>98.33 a</td>
</tr>
<tr>
<td>D2</td>
<td>D1</td>
<td>165.11 bc</td>
<td>199.10 b</td>
<td>19.63 b</td>
<td>21.20 b</td>
<td>13.23 d</td>
<td>3.23 a</td>
<td>5.00 bc</td>
<td>152.76 b</td>
<td>190.56 b</td>
</tr>
<tr>
<td>D3</td>
<td>D1</td>
<td>159.34 c</td>
<td>182.18 bc</td>
<td>20.87 ab</td>
<td>23.31 ab</td>
<td>15.64 b</td>
<td>3.05 a</td>
<td>4.57 bc</td>
<td>220.50 a</td>
<td>270.00 a</td>
</tr>
<tr>
<td>D1</td>
<td>D1</td>
<td>182.09 ab</td>
<td>200.49 b</td>
<td>17.92 b</td>
<td>21.37 b</td>
<td>12.28 d</td>
<td>3.34 a</td>
<td>4.62 bc</td>
<td>78.65 c</td>
<td>97.61 c</td>
</tr>
<tr>
<td>D2</td>
<td>D1</td>
<td>166.20 bc</td>
<td>176.71 c</td>
<td>18.32 b</td>
<td>22.25 b</td>
<td>12.97 d</td>
<td>3.00 a</td>
<td>4.55 bc</td>
<td>149.76 b</td>
<td>189.48 b</td>
</tr>
<tr>
<td>D3</td>
<td>D1</td>
<td>150.46 c</td>
<td>170.62 c</td>
<td>20.00 ab</td>
<td>23.08 ab</td>
<td>14.65 bc</td>
<td>2.68 a</td>
<td>4.10 c</td>
<td>214.56 a</td>
<td>263.52 a</td>
</tr>
<tr>
<td>D1</td>
<td>D1</td>
<td>14.83</td>
<td>19.21</td>
<td>2.34</td>
<td>3.42</td>
<td>1.13 n.s</td>
<td>1.32</td>
<td>31.40</td>
<td>46.13</td>
<td>4.23</td>
</tr>
<tr>
<td>D2</td>
<td>D1</td>
<td>166667D2: 83333D3: 55555 plants/ha</td>
<td></td>
<td></td>
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</tr>
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</table>

Means in the same column followed by the same letters(s) are not significant according to L.S.D_{0.05} values.
maximum total dry forage yield (18.251 t/ha) at 90 (DAS).

On the contrary, decreasing plant density from (166667 to 5555 plants/ha) significantly increased stalk diameter at 55 and 90 (DAS), number of leaves/plant, leaf stem ratio at 90 (DAS), number of ears/plant and plant dry weight at 55 and 90 (DAS), where sowing SC 10 at 5555 plants/ha produced the thickest stalk (22.14 and 26.15 mm) at 55 and 90 DAS, highest number of leaves and ears/plant (17.03 and 1.42), respectively, highest leaf/stem ratio (64.17 %) at 90 (DAS), while the four maize hybrids studied produced the heaviest plant dry weight under the lowest plant density.

From the aforementioned results, it could be conclude that SC 10 white grain maize was significantly surpassed other maize crosses studied under the three plant densities in Al-Maamorah district, El-Ghafara, Tripoli, Libya.

REFERENCE


تأثير الكثافة النباتية على محصول وجودة السيلاج الناتج من بعض هجین الذرة الشامية

محمود أبو عجيبة على رحومة

أجريت هذه الدراسة في مزرعة خاصة بمنطقة المعمورة- الجفارة- طرابلس- ليبيا بهدف دراسة تأثير ثالث
كثافات نباتية (166667، 83333، 55555 ألف نبات/ هكتار) على محصول وجودة السيلاج الناتج من أربعة هجين من الذرة الشامية (SC 10، SC 176، TC 310، TC 360). نفذت التجربة بتصميم القطع المنشقة في ثلاث
مكررات حيث وزعت الهجین عشوائياً على القطع الرئيسية
بينما وزعت الكثافات النباتية عشوائياً على القطع الفرعية
وتشير النتائج إلى تفوق الهجین الفردي (SC 10) على باقي الهجین في صفات ارتفاع النبات وسمك الساق بعد 55، 90
يوم من الزراعة (183.03، 210.93 سم)، (21.08، 24.46
مم) على الترتيب، نسبة الأوراق إلى السيقان (59.06
%) وعدد الأوراق/ النبات (21.2) ومحصول
العلف الجاف بعد 90 يوم من الزراعة (17.059
طن/ هكتار). من جهة أخرى تفوقت الهجین الفردي (10، SC 176)
الهجین الثلاثية في ارتفاع النبات (210.93، 209.72 سم) ودليل المساحة الورقية بعد 90
يوم (6.28، 15.31 مم) وعدد الأوراق على النبات (15.59، 13.708
طن/ هكتار) ومحصول البروتين (1.14، 1.17
طن/ هكتار) لكل هجين على الترتيب.