Dry Matter Accumulation and Partitioning as Affected by Thinning in a Non-Prolific Maize Hybrid

Y. Emam and G. H. Ranjbar

ABSTRACT

The objective of the present field experiment was to examine how plant density and enhanced source, i.e. thinning treatments, may affect grain yield and its components for a non-prolific maize hybrid, SC704. The environment of the hybrid maize crop was changed at intervals over its life cycle by removing every other plant in rows equispaced at 75 cm apart with a population of 13.34 plants m$^{-2}$. The plants were grown with no water or nutrient restrictions. Results showed that earlier thinning was associated with greater stem, leaf, shoot and ear dry weight accumulation, ear kernel weight (EKW) and kernel number per ear row (KNER). In this way the greatest of these characteristics were obtained in thinning at sowing i.e. 6.67 plants m$^{-2}$ throughout. Delay in thinning until the 12-leaf stage reduced stem dry weight and EKW significantly. Thinning at tasseling also resulted in significantly lower stem dry weight accumulation compared to thinning at sowing. At final harvest, the stem dry weight of plants thinned at tasseling was 20.47% (P<0.05) lower than those thinned at sowing. Similar effects were found upon delay in thinning until tasseling on leaf, shoot, and ear dry weight accumulation. Delay in thinning until the 12-leaf stage or later, also reduced EKW significantly compared to plants thinned at sowing. This reduction was attributable to decreased KNER and 1000-kernel weight. According to these results, KNER and 1000-KW were found to be yield components sensitive to light environment.

Keywords: Dry matter partitioning, Maize, Thinning.

INTRODUCTION

Various treatments such as plant density [2,17], shading [1,2,7,12,27,28,29], partial defoliation [2,10,13,25], carbon dioxide enrichment [20,26], and selective grain removal [10] have been imposed in order to investigate the effects of variation in assimilate supply on grain growth. Furthermore, the thinning of dense crops at various stages of growth has been employed to examine the effects of an enhanced source on the remaining plants. Willey and Holliday [29] thinned a wheat crop from establishment to anthesis and showed that, with further delays in thinning, more grain yield reduction occurred. They also concluded that such a reduction was mainly attributable to decreased grains per ear, with little or no change in 1000-kernel weight, although grain yield per plant did decrease with an increase in plant population density. According to Frey [13] source enhancement in maize, achieved by thinning to 50% of stand density, increased the rate of dry matter accumulation, kernel fill and ear dry weight per plant.

Otegui [17] thinned a nonprolific maize crop from 16 to two plants m$^{-2}$ at 50% silking and noted that thinning prevented ear barrenness completely. Plants in the thinned plots always had one ear per plant, whereas 50% of the plants that were planted with only two plants m$^{-2}$ density had two kernel-bearing ears. In this experiment, greater (P<0.01) spikelet abortion occurred at 16 plants m$^{-2}$ density. Fifty percent of the plants, were also barren when grown at 16 plants m$^{-2}$ throughout.

1 Department of Agronomy College of Agriculture, Shiraz University, Islamic Republik of Iran.
Prine [21] reported that individual plants remaining from the high population after thinning treatments, had approximately the same light-intercepting surfaces as those in the low population, i.e. those thinned at sowing. Although thinning treatments undoubtedly cause many favourable environmental changes, change in light has been the main factor thought to be sufficiently altered to cause the plant responses attributed to thinning [21]. Other researchers [e.g. 17,22] have also shown that much of the differences in plant yield of maize (particularly semi-prolific) hybrids, as a result of population change, could be attributed to the above-soil environment when soil moisture and nutrients are adequate. Carbon dioxide, the temperature and light are the principle above-soil environmental factors changed by thinning. According to Prine [21], carbon dioxide and temperature levels are increased very little by thinning, whereas light intensity is greatly increased over the lower shoot due to reduced shading [17,21]. Fischer and Laing [11] also concluded that above-ground competition after anthesis dominante on substantial below-ground competition for nutrients or water which could have taken place before anthesis. Since thinning treatments are relatively easy to carry out and to interpret, at least under irrigated high-fertility conditions, it would appear to be very useful for comparing genotypes and perhaps indicating likely parental combinations for higher yield (for example, by crossing source limited genotypes with source-unlimited ones) [11].

The main objective of the present study was to examine how plant density and enhanced source, i.e. thinning treatments, may affect grain yield and its components for a non-prolific maize hybrid, SC704, which is widely grown in Fars Province of Iran.

MATERIALS AND METHODS

A field experiment was conducted at the Experimental Farm, College of Agriculture, Shiraz University which is located at Kooshkak (longitude 52°, 35' E, and latitude 30°, 4' N) during summer 1999 by using SC704 maize hybrid (Dent, single cross, non-prolific, late maturing). Field soil was classified as fine, mixed Calcixerollic Xerorthents. The experimental design involved randomized complete blocks with three replicates.

Thinning treatments consisted of removing alternate plants in each row at the ground level so that 6.67 plants m⁻² remained after thinning at various stages during the growing season. There were five thinning treatments:

i) at sowing i.e. 6.67 plants m⁻² throughout;
ii) at the 6-leaf stage;
iii) at the 12-leaf stage;
iv) at tasseling (50%); and
v) no-thinning i.e. 13.34 plants m⁻² density throughout.

The thinning treatments are shown diagrammatically in Figure 1. Three kernels were planted in equispaced hills on rows 75 cm apart and later thinned to one plant per hill to give either 13.34 or 6.67 plants m⁻² density, exactly. Each plot consisted of five rows of 8 m long.

Atrazin was applied as a pre-emergence herbicide at a rate of 1 kg ha⁻¹ and a combination of atrazin (1 kg ha⁻¹) and 2,4-D (2.5 kg ha⁻¹) was applied at the 6-leaf stage. Based on soil tests, all plots were fertilized with 80 kg N ha⁻¹ of urea and 85 kg P ha⁻¹ of super phosphate before sowing. At the 6-leaf stage, 170 kg N ha⁻¹ of urea was topdressed to each plot.

All plants received an adequate amount of water during the growing season, as determined by using evaporation pan class A data and the FAO method [6]. The experimental plots were irrigated with 2.5 cm diameter siphons.

During the growing season, small harvests (of three uniform successive plants, surrounded by at least two rows, in the central rows of each plot) were taken. The first sampling was at the 3-leaf stage, and later samplings were carried out at 2-week intervals before tasseling and weekly from tas-
Thinning to physiological maturity (judged by black layer formation in grains at the mid-portion of the ear). The starting of each phase was determined on control plots according to Ritchie and Hanway’s [24] method. Thermal units (°Cd) were calculated from daily mean temperatures above 10°C and accumulated from one day after sowing until physiological maturity. Dry matter accumulation of leaves and stem and shoot above-ground parts were measured for each sample. Ear dry matter accumulation was determined by weekly harvesting of three uniform ears in central rows of each plot from silking until physiological matur-

Table 1. The effect of thinning times on stem dry weight (g plant⁻¹) during the growing season.

<table>
<thead>
<tr>
<th>Thinning at:</th>
<th>Sampling at GDD:</th>
<th></th>
<th>Final harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>During grain</td>
<td>filling</td>
<td></td>
</tr>
<tr>
<td>Sowing(control)</td>
<td>1345</td>
<td>1523</td>
<td>1708</td>
</tr>
<tr>
<td>6-leaf</td>
<td>191.4ab</td>
<td>170.0ab</td>
<td>126.0ab</td>
</tr>
<tr>
<td>12-leaf</td>
<td>177.6b</td>
<td>171.3ab</td>
<td>111.4abc</td>
</tr>
<tr>
<td>Tasseling</td>
<td>178.7b</td>
<td>203.9a</td>
<td>104.9bc</td>
</tr>
<tr>
<td>Harvest (unthinned)</td>
<td>183.1b</td>
<td>159.2b</td>
<td>91.0c</td>
</tr>
</tbody>
</table>

Values in each column not marked with same letter, are significantly different (Duncan 5%).
RESULTS

Earlier thinning was associated with greater stem (Table 1), leaf (Table 2), shoot (Table 3), and ear (Table 4) dry weight accumulation, EKW and KNER (Table 5), so that the greatest of these parameters was obtained in thinning at sowing.

Although thinning at the 6-leaf stage significantly reduced shoot dry weight (Table 3) and ear dry matter accumulation at final harvest (Table 4), it did not affect stem weight (Table 1), leaf dry weight (Table 2), EKW, KNER and 1000-KW (Table 5) at any sampling during the growing season.

Delay in thinning until the 12-leaf stage (889 GDD) reduced stem dry weight significantly compared to thinning at sowing, before sampling at late grain filling (i.e. 1523 GDD). At final harvest, the stem dry weight of plants thinned at tasseling was 20.47% (P<0.05) smaller than those thinned at sowing. The effect of thinning at tasseling on leaf (Table 2) and shoot dry weight accumulation (Table 3) was similar to that on stem dry weight. Thinning at tasseling also resulted in a significant reduction in ear dry weight (Table 4) at final harvest. The effect of thinning at tasseling on EKW was similar to that of thinning at the 12-leaf stage (Table 5).

Compared to thinning at sowing, the most significant reduction in stem (Table 1), leaf (Table 2), shoot (Table 3) and ear dry weight accumulation (Table 4) and in EKW, KNER and 1000-KW (Table 5) was observed in unthinned plots. Furthermore, observations during the growing season indicated that, in unthinned plants, in most cases florets at the tip of the ear were aborted. The stem, leaf, shoot, and ear dry weight of unthinned plots at final harvest were significantly reduced by 31.01, 14.80, 36.10, 42.32% respectively, compared to those thinned at sowing. The reduction in EKW and KNER was 27.90 and 18.84% (P<0.05), respectively (Table 5).

Table 2. The effect of thinning times on leaf dry weight (g plant⁻¹) during growing season.

<table>
<thead>
<tr>
<th>Thinning at:</th>
<th>Sampling at</th>
<th>GDD:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>During grain filling</td>
<td>Final harvest</td>
</tr>
<tr>
<td>Sowing (control)</td>
<td>1345</td>
<td>1708</td>
</tr>
<tr>
<td>6-leaf</td>
<td>95.53a</td>
<td>124.3a</td>
</tr>
<tr>
<td>12-leaf</td>
<td>83.87ab</td>
<td>109.7ab</td>
</tr>
<tr>
<td>Tasseling</td>
<td>76.91b</td>
<td>96.52b</td>
</tr>
<tr>
<td>Harvest (unthinned)</td>
<td>81.99ab</td>
<td>105.9b</td>
</tr>
</tbody>
</table>

Values in each column not marked with same letter are significantly different (Duncan 5%).

Table 3. The effect of thinning times on shoot dry weight (g plant⁻¹) during the growing season.

<table>
<thead>
<tr>
<th>Thinning at:</th>
<th>Sampling at</th>
<th>GDD:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>During grain filling</td>
<td>Final harvest</td>
</tr>
<tr>
<td>Sowing (control)</td>
<td>1345</td>
<td>1708</td>
</tr>
<tr>
<td>6-leaf</td>
<td>556.5ab</td>
<td>713.1b</td>
</tr>
<tr>
<td>12-leaf</td>
<td>460.5b</td>
<td>633.3bc</td>
</tr>
<tr>
<td>Tasseling</td>
<td>457.4b</td>
<td>645.9b</td>
</tr>
<tr>
<td>Harvest (unthinned)</td>
<td>512.0ab</td>
<td>526.2c</td>
</tr>
</tbody>
</table>

Values in each column not marked with same letter are significantly different (Duncan 5%).
DISCUSSION

There is little evidence of interplant competition at early stages of growth in lower population densities [29] such as the 6.67 plants m⁻² in this experiment. According to the results, high plant population until the 6-leaf stage had no reducing effect on shoot dry matter accumulation (Table 3) and EKW (Table 5). This indicated that, until the 6-leaf stage competition, either has not been started or has been relieved by thinning. The increased EKW which occurred when the plants were thinned either at sowing or at the 12-leaf stage, compared to the unthinned treatment (Table 5) implied that, if the ear is developed under conditions of little or no competition, a relatively large ear capacity could be realized [11].

The yield component showing the greatest response to thinning was KNER. It was increased by 18.84% (P<0.05) upon thinning at sowing and at the 6-leaf stage compared to the unthinned treatment (Table 5). As shown in (Table 5), reducing plant population to 50% at each stage produced the same KNER, and it was significantly higher than unthinned plots (p<0.05). Fischer and Laing [11] defined two distinct periods for grain filling duration: in the first half, the photosynthetic rate is greater than demand for kernel growth and photosynthate surplus is reserved in temporary storage organs (such as the stem); and in the latter half, due to a high demand of kernel growth photosynthate from temporary storage in the stems, are translocated to the kernels. As shown in (Table 1) in all thinning treatments, except in those thinned at tasseling, maximum stem dry weight was obtained at early grain filling i.e. 1345 GDD. However, in plants thinned at tasseling treatment stem dry weight was increased up to 1523 GDD. It seems likely that, after thinning at tasseling and due to increased light interception by the remaining plants [11,18,21], the photosynthetic rate might have been increased [11] and an additional amount of current photosynthate has probably been stored in the stem. Due to high demand in the second half of the grain filling, i.e. from 1523 GDD onwards, extra photosynthate from a temporary storage pool in the stem has possibly translocated to the kernels so that, at final harvest, EKW of plants thinned at tasseling was significantly different from those thinned at the 6-leaf stage (Table 5). It appeared that thinning at each phase has increased the light intercepted by the remaining plants [11,17,21]

Table 4. The effect of thinning times on ear dry weight during the (g plant⁻¹) growing season.

<p>| Sampling at | GDD: |</p>
<table>
<thead>
<tr>
<th>Thinning at:</th>
<th>During grain filling</th>
<th>Final harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing (control)</td>
<td>1263</td>
<td>1345</td>
</tr>
<tr>
<td>6-leaf</td>
<td>191.0ab</td>
<td>295.9ab</td>
</tr>
<tr>
<td>12-leaf</td>
<td>280.0a</td>
<td>283.3ab</td>
</tr>
<tr>
<td>Tasseling</td>
<td>206.5ab</td>
<td>196.5b</td>
</tr>
<tr>
<td>Harvest (unthinned)</td>
<td>238.3ab</td>
<td>223.4ab</td>
</tr>
</tbody>
</table>

*aValues in each column not marked with same letter are significantly different (Duncan 5%).

Table 5. The effect of thinning times on ear kernel weight (EKW) (g plant⁻¹), kernel number per ear row (KNER) and 1000-kernels weight (1000-KW) (g) of maize at final harvest.

<table>
<thead>
<tr>
<th>Thinning at:</th>
<th>EKW (g plant⁻¹)</th>
<th>KNER</th>
<th>1000-KW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing (control)</td>
<td>158.40a</td>
<td>38.69a</td>
<td>291.10a</td>
</tr>
<tr>
<td>6-leaf</td>
<td>143.30ab</td>
<td>38.69a</td>
<td>287.8ab</td>
</tr>
<tr>
<td>12-leaf</td>
<td>134.00ab</td>
<td>34.94ab</td>
<td>280.0ab</td>
</tr>
<tr>
<td>Tasseling</td>
<td>129.70ab</td>
<td>34.76ab</td>
<td>279.5ab</td>
</tr>
<tr>
<td>Harvest (unthinned)</td>
<td>114.20c</td>
<td>31.40b</td>
<td>261.5b</td>
</tr>
</tbody>
</table>

*aValues in each column not marked with same letter are significantly different (Duncan 5%).
and, thereby, increased the photosynthate supply (source) [11,17] which resulted in similar KNER for all thinning treatments (Table 5). These findings are in agreement with the observation made by Ottman and Welch [19], who found a significant (P<0.05) increase in the number of ears per plant (in a prolific maize) and kernels per ear using different levels of supplemental radiation after silking. Reduction in the KNER promoted by severe defoliation soon after silking [16] is also consistent with this finding.

Otegui [17] concluded that spikelet abortion on the ear might not be related to differences in floral differentiation along the rows, but to differences in pollination date. In other words, delays in the emergence [3] and pollination [18] of silks from the ear tip may limit assimilate availability to apical kernels. Bonnett [5] also noted that floret primordia are initiated acropetally, and the development of lower central florets at the commencement of silk growth is often slightly ahead of that of basal florets and generally well ahead of tip florets. In the present study, the ear tip floret abortion observed in unthinned plants was the reason for the reduction in KNER (Table 5) resulting from source limitations during grain filling. Otegúi [17] have reported similar results with regard to maize as have Fischer and Laing [11] with regard to wheat.

1000-KW was also affected by thinning treatments in a similar way to KNER (Table 5). It might therefore be concluded that, compared to unthinned plots, 1000-KW was probably limited by source during the grain filling period since, in many cases as in this experiment where every other plant on each row was thinned by hand, thinning means more light reaching the remaining plants compared with unthinned plots, [11,18,21]. Thus, it might be concluded that KNER and 1000-KW have been yield components sensitive to the light environment.

REFERENCES


**Thinning in Non-Prolific Maize Hybrid**


**نجم و تسهیم ماده خشک تحت تأثیر تکن کردن در ذرت هبهیرید تک بلالی**

ی. امام و غ. ر. رنجر

چکیده

هدف از این آزمایش مزروعهای ارزیابی تأثیر تراکم زیاد بوته و افزایش اندازه میدان از طریق تکن کردن بوته‌ها، بر عملکرد دانه‌کننده روی تراکم بوته و افزایش آن در ذرت دانه‌کننده هبهیرید (SC704) بود. می‌تواند تراکم این هبهیرید در ذرت می‌تواند با حدف دانه‌کننده به ویژه در دانه‌کننده از گیاهانی که با فاصله سنگین از هم و در روی درفته‌های 5 هزار تراکم 13/24 بوده در مترمربع کشت شده باشد، نگه داشته شود. نتایج نشان داد که تکن کردن زود هبهیرید با بیشترین ماده خشک ساقه، بیشتر، گسترش‌های هوا به تکن بوته، بالند، وزن دانه بالل و تعداد دانه در دانه تراکم 13/24، وزن هزار دانه (EKW) و وزن هزار دانه (1000-KW) همراه بوده، به طوری که بیشترین مقادیر این پارامترها به وسیله تکن کردن در زمان کاشت 7/7 به ترویج در مترمربع تا یا پایان فصل

271
رشد) بدست آمد. تأخیر در تنسک کردن تا مرحله 12 برگی وزن خشک ساقه را به طور معنی‌داری کاهش داد. تنسک کردن در زمان ظهور گل ناحیه تجمع ماده خشک ساقه را به طور معنی‌دار نسبت به تنسک کردن در زمان‌های نهایی وزن ماده خشک ساقه مربوط به تیمار تنسک کردن در زمان ظهور گل ناحیه 7/47 (P<0.05) کمتر از تنسک کردن در زمان کاشت بود. تأثیر تنسک کردن در زمان ظهور گل ناحیه بر تجمع ماده خشک برگ، قسمت‌های هوایی و بلال مشابه تأثیر آن بر وزن ماده خشک ساقه بود. به طور معنی‌دار تحت تأثیر تاخیر در تنسک تا مرحله 12 برگی کاهش یافت. کاهش در برگی کاهش بیانی به میزان زیادی به کاهش KNER و 1000-KW مربوط بود. براساس این نتایج، به نظر می‌رسد که مرحله 12 برگی در نحو دزرت تحت تراکم زیاد یک مرحله بحرازی است.