J. Agric. Sci. Technol. (2001) Vol. 3: 265-272

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

Y. Emam[1] and G. H. Ranjbar[1]

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 ways 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.

[DOR: 20.1001.1.16807073.2001.3.4.5.4]

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 grian 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 Rebublic 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 Xerocherepts. 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 diagramatically 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-

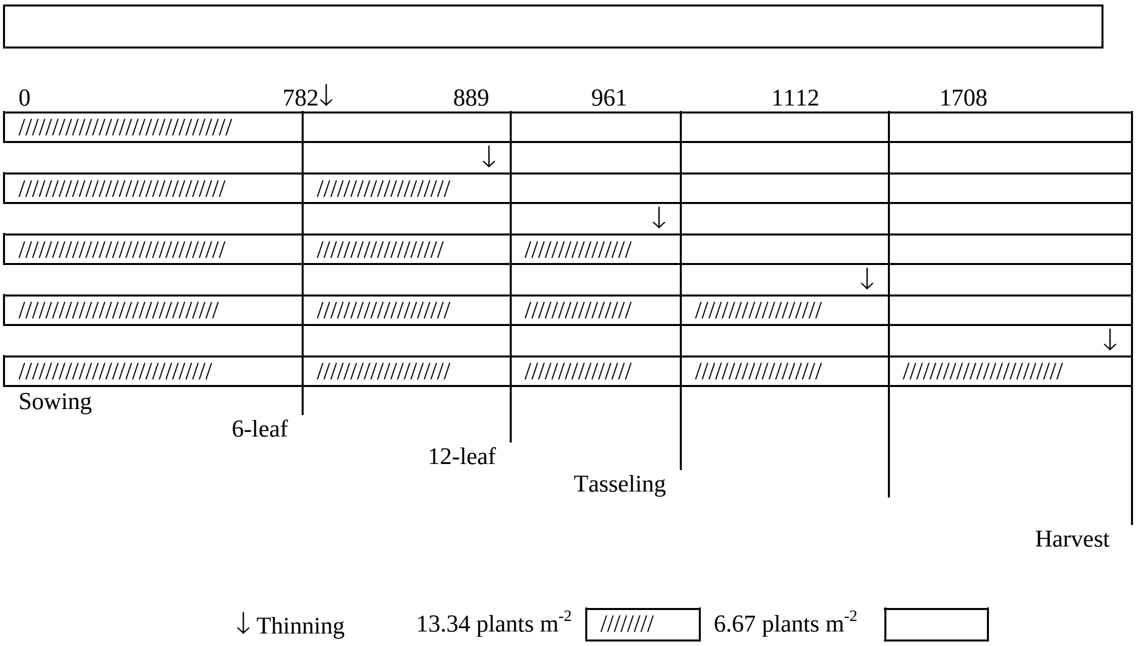

Figure 1. Details of thinning treatments.

seling 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 maturity. At final harvest, ten uniform ears were harvested from the central area of each plot. Ears were individually shelled and the kernel number per ear row (KNER) was calculated. Kernel row number per ear (KRNE), ear kernels weight (EKW) and 1000-kernels weight (1000-KW) were also determined. For dry weight determination, all samples were oven-dried to a constant weight at 82°C.

The collected data were subjected to variance analysis using MSTATC software. Statistically significant differences among the means were determined by using Duncan's new multiple range test.

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

	Sampling at GDD: During grain filling		Final harvest
Thinning at:	1345	1523	1708
Sowing(control)	217.2a[a]	208.4a	131.9a
6-leaf	191.4ab	170.0ab	126.0ab
12-leaf	177.6b	171.3ab	111.4abc
Tasseling	178.7b	203.9a	104.9bc
Harvest (unthinned)	183.1b	159.2b	91.0c

[a] 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) (Table 1). The effect of this thinning treatment on leaf dry weight was significant in all samplings compared to thinning at sowing (Table 2), such that it decreased leaf dry weight at final harvest by 22.35% ($P<0.05$) (Table 2). A similar reduction was also observed in ear dry weight at final harvest, i.e. 24.65% ($P<0.05$) lower than thinning at sowing (Table 4). Furthermore, delay in thinning until the 12-leaf stage reduced EKW significantly, compared to plants thinned at sowing treatment.

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

	Sampling at:	GDD:
	During grain filling	Final harvest
Thinning at:	1345	1708
Sowing(control)	95.53a[a]	124.3a
6-leaf	83.87ab	109.7ab
12-leaf	76.91b	96.52b
Tasseling	77.32b	99.67b
Harvest (unthinned)	81.99ab	105.9b

[a]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^{-3}) during the growing season.

	Sampling at	GDD:
	During grain filling	Final harvest
Thinning at:	1345	1708
Sowing(control)	611.9a[a]	823.5a
6-leaf	556.5ab	713.1b
12-leaf	460.5b	633.3bc
Tasseling	457.4b	645.9b
Harvest (unthinned)	512.0ab	526.2c

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

The effect of thinning at tasseling (i.e. 961 GDD) on stem dry weight is shown in Table1. According to this table, stem dry matter accumulation was significantly lower than thinning at sowing in all samplings during the growing season, except at 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 (Table5).

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).

[DOR: 20.1001.1.16807073.2001.3.4.5.4]

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

	Sampling at	GDD:	
	During grain	filling	Final harvest
Thinning at:	1263	1345	1708
Sowing(control)	191.0ab[a]	295.9ab	573.2a
6-leaf	280.0a	283.3ab	478.7b
12-leaf	206.5ab	196.5b	431.9b
Tasseling	238.3ab	223.4ab	435.0b
Harvest (unthinned)	195.8ab	246.9ab	330.6c

[a]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 phothosynthate surplus is reserved in temporary storage organs (such as the stem); and in the latter half, due to a high demand of kernel growth phothosynthate 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 phothosynthetic rate might have been increased [11] and an additional amount of current phothosynthate 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 phothosynthate 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 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.

Thinning at:	EKW (g plant^{-1})	KNER	1000-KW(g)
Sowing(control)	158.40a[a]	38.69a	291.10a
6-leaf	143.30ab	38.69a	287.8ab
12-leaf	134.00b	34.76ab	280.0ab
Tasseling	129.70b	34.94ab	279.5ab
Harvest (unthinned)	114.20c	31.40b	261.5b

[a]Values 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 splikelet 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. Bonnet [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. Oteguie [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

1. Andrade, F.H., Uhart, S.A., and Frugone, M. 1993. Intercepted Radiation at Flowering and Kernel Number in Maize: Shade Versus Plant Density Effects. *Crop Sci*., **33**: 482-485.
2. Andrade, H.F., Otegui, M.E., and Vega, C. 2000. Intercepted Radiation at Flowring and Kernel Number in Maize. *Agron. J*., **92**: 92-97.
3. Bassetti, P., and Westgate, M.E. 1993. Emergence, Elongation and Senescence of Maize silks. *Crop Sci*., **33**: 271- 275.
4. Below, F.E., Christensen, L.E., Reed, A.J., and Hageman, R.H. 1981. Availability of Reduced N and Carbohydrate for Ear Development of Maize. *Plant Physiol*., **68**: 1186-1190.
5. Bonnett, O. T. 1966. Inflorescences of Maize, Wheat, Rye, Barley and Oats: their Initiation and Development. *Univ. Ill. Agr. Exp. Sta. Bull*., **721**. 105 pp.
6. Cuenca, R.H. 1989. Irrigation Systems Design, an Engineering Approach. *Printice-Hall Inc. NJ*. 552 pp.
7. Early, E.B., McIlrath, W.O., Seif, R.D., and Hageman, R.H. 1967. Effect of Shade Applied at Different Stages of Plant Development on Corn Production. *Crop Sci.*, **7**: 151-156.
8. Edmeads, G.O., and Daynard, T.B. 1979. The Development of Plant-to-plant Variability in Maize at Different Planting Densities. *Can. J. Plant Sci*., **59**: 561- 576.
9. Fairy, N.A., and Daynard, T.B. 1978. Quantitative Distribution of Assimilates in Component Organs of Maize During Reproductive Growth. *Can. J. Plant Sci*., **58**: 709-717.
10. Ficher, R.A., and HilleRisLambers, D. 1978. Effect of Environment and Cultivar on Source Limitation to Grain Weight in Wheat. *Aust. J. Agr. Res*., **29**: 443- 453.
11. Ficher, R.A., and Laing D. R. 1976. Yield Potential in a Dwarf Spring Wheat and Response to Crop Thinning. *J. Agr. Sci. Camb*., **87**: 113- 122.
12. Fischer, R.A., and Stockman, Y.M. 1980. Kernel Number per Spike in Wheat: Response to Pre-anthesis Shading. *Aust. J. Plant Physiol*., **7**: 169- 180.
13. Frey, N.M.1981. Dry Matter Accumulation in Kernels of Maize. *Crop Sci*., **21**: 118- 122.

14. Hume, D.J., and Campbell, D.K. 1972. Accumulation and Translocation of Soluble Solid in Corn Stalks. *Can. J. Plant Sci*., **52**: 363- 368.
15. Johnson, D.R. and Tanner, J.W. 1972. Compartion of Corn (*Zea mays* L.) Inbreds and Hybrids Grown at Equal Leaf Area Index, Light Penetration and Population. *Crop Sci*., **12**: 482- 485.
16. Jones, R.J., and Simmons, S.R. 1983. Effect of Altered Source-sink Ratio on Growth of Maize Kernels. *Crop Sci*., **23**: 129- 134.
17. Otegui, M.E. 1997. Kernel Set and Flower Synchrony Within the Ear of Maize: II. Plant Population Effects. *Crop Sci*., **37**: 448- 455.
18. Otegui, M.E., Andrade, F.H. and Suero, E.E. 1995. Growth, Water Use and Kernel Abortion of Maize Subjected to Drought at Silking. *Field Crops Res.*, **40**: 87-94.
19. Ottman, M.J., and Welch, L.F. 1988. Supplemental Radiation Effects on Senescence, Plant Nutrients, and Yield of Field Grown Corn. *Agron. J*., **80**: 619- 626.
20. Outlaw, W.H., Fisher, B.D., and Christy, A.L. 1975. Compartmentation in *Vicia Faba* Leaves. II: Kinetcs of ^{14}C-source Redistribution Among Individual Tissues Following Pulse Labeling. *Plant Physiol*., **55**:704- 711.
21. Prine, G.M. 1971. A Critical Period for Development in Maize. *Crop Sci*., **11**: 782- 786.
22. Prine, G.M., and Schroder, V.N. 1964. Above-soil Environment Limit Yields of Semiprolific Corn as Plant Population Increase. *Crop Sci*., **4**: 361-362.
23. Puckridge, D.W. 1968. Competition for Light and Its Effect on Leaf and Spikelet Development of Wheat Plants. *Aust. J. Agr. Res.*, **19**: 191-201.
24. Ritchei, J.T., and Hanway, J. J. 1992. How a Corn Plant Develops. *Iowa Coop. Ext. Serv. Spec. Rep*. 48 pp.
25. Seghatoleslami M.J. and Emam, Y. 1998. Effect of Defoliation on Yield and Water Use Efficiency of Maize. *Iran. J. Crop Sci* (in persian)., **1**:30- 42.
26. Servaites, J.C., and Geiger, D.R. 1974. Effect of High Intensity and Oxygen on Photosynthesis and Translocation in Suger Beet. *Plant Physiol*., **54**: 575- 578.
27. Stockman, Y.M., Fischer, R.A., and Brittain, E.G. 1983. Assimilate Supply and Floret Development Within the Spike of Wheat. *Aust. J. Plant Physiol.*, **10**: 585- 594.
28. Willey, R.W., and Holliday, R. 1971. Plant Population and Shading Studies in Barley. *J. Agr. Sci. Camb*., **77**: 445- 452.
29. Willey, R.W., and Holliday, R. 1971. Plant Population, Shading and Thinnig Studies in Wheat. *J. Agr. Sci. Camb*., **77**: 453- 461.

تجمع و تسهیم ماده خشک تحت تاثیر تنک کردن در ذرت هیبرید تک بلالی

ی. امام و غ. ح. رنجبر

چکیده

هدف از این آزمایش مزرعه‌ای ارزیابی تاثیر تراکم زیاد بوته و افزایش اندازه مبداء، از طریق تنک کردن بوته‌ها، بر عملکرد دانه تک بوته و اجزای آن در ذرت دانه‌ای هیبرید (SC704) بود. محیط زندگی این هیبرید ذرت در طی چرخه زندگی با حذف یک درمیان بوته‌ها از گیاهانی که با فاصله مساوی از هم در روی ردیف‌های ۷۵ سانتی‌متری و با تراکم ۱۳/۳٤ بوته درمترمربع کشت شده بودند، تغییر یافت. نتایج نشان داد که تنک زود هنگام با بیشترین ماده خشک ساقه، برگ، قسمت‌های هوایی تک بوته، بلال، وزن دانه بلال(EKW) ، تعداد دانه در ردیف بلال (KNER) و وزن هزار دانه (1000-KW) همراه بود، به طوری که بیشترین مقدار این پارامترها به وسیله تنک کردن در زمان کاشت (٦/٦٧ بوته در مترمربع تا پایان فصل

رشد) بدست آمد. تاخیر در تنک کردن تا مرحله ۱۲ برگی وزن خشک ساقه را به طور معنی‌دار کاهش داد. تنک کردن در زمان ظهور گل تاجی تجمع ماده خشک ساقه را به طور معنی‌دار نسبت به تنک کردن در زمان کاشت درتمام نمونه‌برداری‌های طول فصل رشد کاهش داد. در برداشت نهایی وزن ماده خشک ساقه مربوط به تیمار تنک کردن در زمان ظهور گل‌تاجی ۲۰/۴۷٪ ($P<0.05$) کمتر از تنک کردن در زمان کاشت بود. تاثیر تنک کردن در زمان ظهور گل‌تاجی بر تجمع ماده خشک برگ، قسمتهای هوایی و بلال مشابه تاثیر آن بر وزن ماده خشک ساقه بود. EKW به طور معنی‌دار تحت تاثیر تاخیر در تنک تا مرحله ۱۲ برگی کاهش یافت. کاهش در EKW به میزان زیادی به کاهش KNER و 1000-KW مربوط بود. براساس این نتایج، به نظر می‌رسد که مرحله ۱۲ برگی در نمو ذرت تحت تراکم زیاد یک مرحله بحرانی است.