The Journal of Animal & Plant Sciences, 21(4): 2011, Page: 696-699
ISSN: 1018-7081

SHOOT GROWTH CURVE ANALYSIS OF MAIZE CULTVARS UNDER BORON DEFICIENCY

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ABSTRACT

This research was conducted in 2003-2004 in Karaaslan, Soil and Water Sources Research Institute, Konya the largest province in Central Anatolia Region. There is boron deficiency in soils. Thirteen corn cultivars (TTM 8119, MAT 97, RX 770, PİAVE, DK 585, DK 647, LUCE, TTM 815, LG 55, LG 60, T 1595, BC 566 and P 3394) were tested in completely randomized design with four replications. 0 (B-)-deficiency- and 3.0 kg B/ha (B+) of boron levels were applied as boric acid (H_3BO_3) before seed sowing. Richards Model was used estimation of growth. The Weighted Sum of Squares of Residual (WSS), the Akaike Information Criterion (AIC) and the Schwartz criterion (SC) were used as comparison criteria. As result, 3.0 kg B/ha (B+) dose revealed better growth than 0 (B-). Average dry matter accumulation in boron deficient plots (245.3 g/plant) was lower than the other plots (263.8 g/plant). But, boron deficiency of plot yields (1028.8 kg/da) was higher than for other plot yields (1024.8 kg/da).

Key words: Boron deficiency, Maize cultivar, Richard growth model, comparison criteria.

INTRODUCTION

Micronutrients are essential for the growth of plants. Deficiencies of micronutrient drastically affect the growth, metabolism and reproductive phase in plants (Cartwright et. al, 1983). Both macro and micronutrients are essential for plant growth and if a plant does not get enough of a particular nutrient it needs, the deficiency symptoms show in the general appearance of the plant. Despite being needed in small quantities, micronutrients are essential for the overall performance and health of the maize crop. They include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and boron (B). Due to cropping practices and poor soil management, soil reserves are depleting in many arable soils and nutrient deficiencies have been linked to low maize yields across Middle Anatolia. Wide spread deficiencies of micronutrients has been found in Soils of Central Turkey (Alkan et. al., 1995). Soils of Central Anatolia are generally highly calcareous. Boron deficiency varies from 2% to 30 % in highly calcareous soils (Palta, 2006). B deficiency depresses commercial corn yield primarily through grain set failure. Boron deficiencies are usually apparent on the new leaves of maize since it is during the development of new tissue that nutrients are most required Raid *et al*., (2004). Symptoms may be reversed using boron fertilizer.

Crop growth models have made considerable progress in recent years and their predictive value is now quite acceptable under non-limiting conditions. However, under nutrient limited conditions, their predictive value is still poor. So far, a so-called “stress factor” is often used to account for the lower biomass production, but the exact steps of the biomass production process which are affected by nutrient deficiency are not well identified (Pelerin and Mollier, 2001). Palta *et al*., (2008) compared maize cultivars with Richards growth model under effect of boron toxicity. Boron toxicity affected significantly on dry matter accumulation in maize cultivar. Boron availability is reduced under low rainfall/drought conditions or in soils low in organic matter. Farmers maintaining high levels of organic matter in their fields normally do not face boron deficiencies (Goldberg, 1997; Palta, 2006). Kakar *et al*. (2002) explained that 2 kg ha^{-1} boron doses increased biomass yield in wheat cultivars and logistic growth model fitted higher than other models.

The mechanism for loss due to B deficiency in maize has yet to be identified. There is little information about B deficiency in maize. Therefore, the objective of this study was to determine the maize growth under boron deficiency in Central Anatolian Region.

MATERIALS AND METHODS

The present research was conducted in 2003-2004 in Karaaslan, Soil and Water Sources Research Institute, Konya the largest province in Central Anatolia Region. In growing season of corn average temperature were 18.2 and 17.7^{o}C, rainfall and humidity were 15.6, 20.0 mm and 50.2, 49.1%, in 2003 and 2004, respectively. Soils of research area have clay-loam texture, alkali (pH: 8.2), cancerously (21.8%) and slightly salt. Also, soils have low organic matter (1.04%), lime level (7.4%) but high potassium (1.812 ppm) and phosphorous (27.1 ppm). Boron level was very low (0.25 ppm) in soil of experimental area.

Thirteen corn cultivars (TTM 8119, MAT 97, RX 770, PİAVE, DK 585, DK 647, LUCE, TTM 815, LG 55, LG 60, T 1595, BC 566 and P 3394) were tested in completely randomized design with four replications. Each plot was 3.0 m x 5.0 m = 15 m^2. Planting distance was 0.75 m between rows and 0.25 m between plants to give a plant population of 53 333 plants/ha. At planting, P in the form of single superphosphate was applied at 80 kg/ha each; N was applied at 150 kg /ha in the form urea. The N fertilizer was applied in two equal splits; 75 kg N/ha at planting and the other half, 10 weeks after planting. 0 (B-) and 3.0 kg B/ha (B+) of boron levels were applied as boric acid (H_3BO_3) before seed sowing. Weeding was done twice by hand hoeing when the plants were 15-20 and 35-40 cm tall.

The data were collected weekly from 5 plants that were randomly selected in each plot. Maize plants at each sampling were separated into roots and shoots. The plants were oven-dried and weighted to record shoot weight. Non linear growth functions are the most appropriate for describing changes in weight with time because growth functions account for the form of the growth processes (Richards, 1969).

Richards Model was used in this study.

Richards Model;

$$Y = \frac{\alpha}{(1 + e^{\beta - \kappa x})^{1/\delta}}$$

where, α; the value of asymptote, β; value of growth beginning stage, κ; net growth ratio, δ; parameter at inflexion point. Model selection, in terms of best fitting, was based on three basic diagnostic tools. The Weighted Sum of Squares of Residual (WSS), the Akaike Information Criterion (AIC) and the Schwartz criterion (SC) were used as comparison criteria. These criteria are given below;

a) Coefficient Determination (R^2)

$$= 1 - \frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n} (Y_i - \bar{Y}_i)^2}$$

b) Weighted Sum of Squares of Residual (WSS)

$$WSS = \sum_{i=1}^{n} \frac{1}{SD^2} (Y_{observed} - Y_{calculated})$$

c) Akaike Information Criterion (AIC)

$$AIC = N \log(WSS) + 2M$$

d) Schwartz Criterion (SC)

$$SC = N \ln(WSS) + \ln(N).M$$

where, N; number of observation, M; number of parameters, SD; standard deviation for the mean size at age. The best model was selected as WSS, AIC and SC were lower than others. Data were analyzed by STATISTICA 5.0 statistical package program.

RESULTS AND DISCUSSION

Boron deficiency depressed dry matter accumulation in corn cultivars. Especially, it affects vegetative and reproductive stages of plant growth and leads to inhibition of plant growth (Goldbach, 1997). Maize plants differ in their B requirement. Richards model generally gave a reasonable fit. The *R^2, WSS, AIC* and SC were evaluated for each cultivar. Total dry matter at maturity, comparison criteria and grain yield are shown in Table 1 and distribution of dry matter, R^2, WSS, AIC and SC in Boron level (B-) and (B+) presented in weight or level Figure 1 and 2. Shoot of plants varied according to cultivars. Shoot of plants ranges from 238.0 g (DK 647) to 275.6 g (TTM 8119) in 0.0 kg ha^{-1} boron doses. But, Shoot of plants ranges from 256.4 g (T 1595) to 296.2 g (TTM 8119) in 3.0 kg ha^{-1} boron doses. M 8119 cultivar had the higher dry matter accumulation in shoot than other cultivars. We considered value of R^2 as a tool to make comparative study for cultivars. Coefficient of Determination (R^2) ranges from 92.3 (DK 647) to 80.5 (LG 60) in 0.0 kg ha^{-1} boron doses and it ranges from 95.6 (T 1595) to 85.3 (LG 60) in 3.0 kg ha^{-1} boron doses. LUCE cultivar is successfully determined by Richards's model. Comparison criteria WSS, AIC and SC are the lower than other criteria (16.4, 85.8 and 195.7) in 0.0 kg ha^{-1} boron doses. TTM 8119 cultivar is successfully determined by Richards's model. Comparison criteria WSS, AIC and SC are lower than other criteria (14.1, 81.6 and 169.4) in 3.0 kg ha^{-1} boron doses.

Grain yield range from 1236 kg da^{-1} (DK 585) to 924 kg da^{-1} (MAT 97). When level of boron increased, yield decreased significantly. TTM 8119 cultivar revealed the highest reduction (14.2%). The lowest reduction was shown in LUCE cultivar (0.6%). However, T1595, P3394 and BC 566 cultivars revealed rising (13.9%, 19.9% and 0.1%, respectively). These cultivars benefit from boron toxicity. Palta (2006) explained that boron deficiency decreased maize cultivars yield significantly. This study was supported by Palta (2006).

Growth of shoot revealed nearly identically S shaped all cultivars. The board range of genotypes revealed a close relationship between shoot and growing season. The increased variation was due to a change in cultivar characteristics with ontogeny and possibly by the normal tendency for the variance of variable to increase in proportion to the mean of the variable (Ma et. al., 1992). An enhanced B deficiency symptoms in plants by increased Ca supply have been reported (Gupta, 1979). Genotypic variation in crops has also been reported with respect to B and Ca uptake (Huo-yan *et al*., 2003; Kanwal et. al, 2008). Boron availability in soil is affected by several factors including soil texture, nature of clay minerals, pH, liming, organic matter, interrelationships with other elements, and environmental conditions like moderate to heavy rainfall, dry weather, and high light intensity (Moraghan and Mascagni, 1991). In addition to its effect on soil pH, calcium carbonate also acts as an important B adsorbent in calcareous soils (Goldberg and Forster, 1991). Germination rate differed significantly according to cultivars. Boron deficiency or toxicity revealed on photosynthesis are primary or secondary, or early or late, effects in leaves (Bolan˜os *et al.*,2004; Reid *et al.*, 2004).

Table 1. Total Dry Matter at Maturity, comparison criteria and grain yield

Cultivars	Total Dry Matter at Maturity (g/plant)										Grain Yield (kg/da)	
	B-	R^2	WSS	AIC	SC	B+	R^2	WSS	AIC	SC	B-	B+
TTM 8119	275.6	91.7	18.0	88.3	201.6	296.2	95.6	14.1	81.6	169.4	951	854
MAT 97	238.8	88.6	20.6	92.1	210.3	256.5	91.3	17.3	87.2	182.4	924	985
RX 770	245.6	88.5	20.2	91.5	209.0	263.8	88.7	22.6	94.7	199.5	976	1031
PİAVE	240.0	85.3	22.2	94.2	215.0	265.4	90.1	18.7	89.4	187.4	1026	1016
DK 585	241.5	90.6	19.3	90.3	206.1	260.3	92.3	16.1	85.2	177.8	1236	1084
DK 647	238.0	92.3	16.4	85.8	195.7	256.9	93.7	15.8	84.7	176.6	1109	1057
LUCE	242.6	87.7	19.9	91.1	208.0	258.3	90.1	18.8	89.5	187.8	943	961
TTM 815	248.5	91.8	17.5	87.6	199.8	260.0	92.3	16.2	85.4	178.2	1065	1131
LG 55	246.3	82.8	26.4	99.0	226.1	265.3	86.7	24.4	96.8	204.5	1095	1070
LG 60	248.1	80.5	31.2	103.6	236.8	266.9	85.3	26.1	98.7	208.8	1009	1058
T 1595	242.9	90.1	19.8	91.0	207.7	256.4	93.0	15.9	84.9	177.0	967	976
BC 566	238.9	87.3	19.3	90.3	206.1	260.7	90.4	18	88.3	185.0	986	976
P 3394	242.7	90.7	19.8	91.0	207.7	262.3	93.9	15.4	84.0	175.0	1087	1124

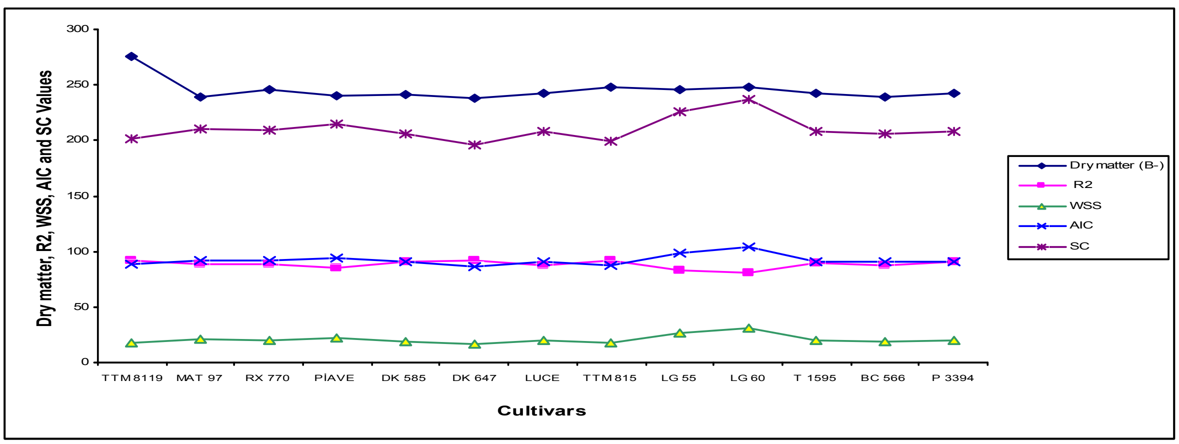

Figure 1. Distribution of dry matter, R^2, WSS, AIC and SC in Boron level (B-)

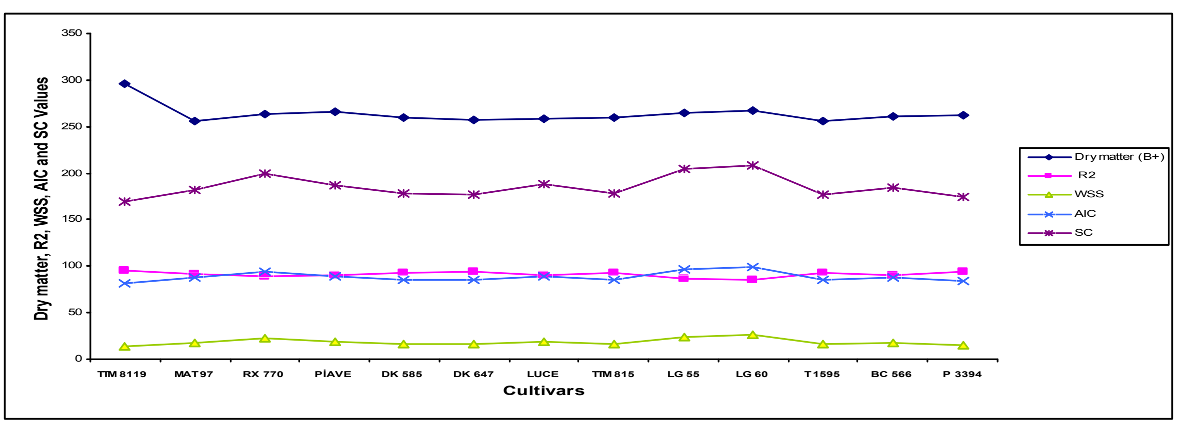

Figure 2. Distribution of dry matter, R^2, WSS, AIC and SC in Boron level (B+)

Variation in shoot growth may explain this situation. Because, germination rate, lengths of roots and shoots as well as dry matter production decreased with increasing B concentration (Ismail, 2003). The concentration of B in shoot can be affected by the inherently different growth rates (dry matter production rates) of genotypes, which can cause a dilution or concentration effects on the B concentration in the tissue. It was interesting to notice that there was a very clear inverse relationship between the total amount of B per shoot and the decreases in shoot dry matter production by B toxicity. These findings are supported by Torun *et al*., (2006).

The nonlinear investigation of the growth process has some advantages in not only mathematically explaining growth but also estimating the relationship among plant organs. Furthermore, nonlinear estimation techniques may contribute to determining of the economic information in plant growth mechanism. In this study, Richards growth model is found to be suitable models to fit maize leaf growth data.

Boron toxicity is an important disorder that can limit plant growth on soils of arid and semi arid environments throughout the world. A general antagonistic relationship between boron excess and salinity has been observed. We determined that low boron level affected negatively maize cultivar. The activity of specific membrane components can be influenced directly by boron toxicity, regulating the water uptake and water transport. Generally, effects of boron toxicity decreased dry matter accumulation and seed yield. But, growth model determined better this situation than normal boron level. In future, more extensive studies may be done on this subject of considerable importance.

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