EFFECT OF PLANTING DATE AND DENSITY ON AMARANTH (Amaranthus hypochondriacus L.) GROWTH INDICES AND FORAGE YIELD

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ABSTRACT

To study the effects of planting date and plant density on Amaranth, two field experiments were conducted in 2013 at Marv-Dasht, Fars, Iran. The field experiments were conducted as split plot in a randomized complete block design with 3 replications. Plant density (6.6, 8.3 and 11.0 Plant.m⁻²) and planting date (June 22nd, July 6th and July 21st) were used as treatments. Results of this study revealed that the planting date and plant density had significant effect on number of leaf per plant, stem diameter, leaf dry weight, stem dry weight, forage yield, relative growth rate (RGR), crop growth rate (CGR) and leaf area index (LAI). Highest amaranth forage yield (11.7t.ha⁻¹) was obtained from 6.6 plant.m⁻² density and July 6th planting date. Moreover, in the experiment condition the amaranth yield was also reduced with delay in planting date from 6th to 21st July and increases the plant density from 6.6 to 11 plant.m⁻² significantly.

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1 Introduction

Amaranth (Amaranthus hypochondriacus) belongs to family of Amaranthaceae, used as livestock feed because of high percent of seed protein. Further use of amaranth as forage in tropical zone is also supported by its higher growth and development potential under tropical conditions (Kauffman, 1992). In recent decade’s frequency of its consumption widely increased in various continents such as China, Eastern South of Asia, Africa and America (Becker et al., 1981; Ravindran et al., 1996). Amaranth produced high amount of forage in a short period which can be used as dry forage or grain depot for ruminator and non-ruminator livestock (Sleugh et al., 2001). In terms of quality and protein level of amaranth it keeps pace with legumes plants or some time may have higher protein level than the leguminous crops (Sleugh et al., 2001). One of the most important features of amaranth is consumption of less water for normal growth (42-47 percent) as compared to other crops (Johnson & Henderson, 2002). Cultivation of this crop is affected by various factors such as seed quality, nitrogen level, planting date and plant densities (Rabbani et al., 2012).

According to Ansariardali & Aghaalikhani (2013) plant density and nitrogen level have significant effect the yield and quality of amaranth, these researchers reported that the treatment containing 180 kg per hectare nitrogen fertilizer and 140000 plants per hectare showed superiority over the other treatment and represent better agronomic characteristics. Further, effect of planting date on growth and performance of this crop was also studied by Aynehband et al. (2007) and reported that planting date also had an effect on the growth of crop and highest plant growth was reported from the crop grown in late July or early August and on this date plant also produced highest plant growth was reported from the crop gared during the plant growth period. To measure the plant growth indices like, Leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) leaf area and plant dry weight was measured every two weeks from 30 days after planting dates as described by Gardner et al. (1991).

Field experiments were conducted at two locations at the same time as split plot in a randomized complete block design with 3 replications. Plant density (6.6, 8.3 and 11.0 Plant.m−2) and planting date (June 22nd, July 6th and July 21st) were used as treatments. Seedbed preparation consisted of spring disking and moldboard plowing. Amaranth seeds were planted at 1-1.5 cm depth in different plant density in 60 cm spaced rows. Various attributes such as forage yield, stem diameter, number of leaves per plant, leaf dry weight, stem dry weight were measured at harvesting time. Irrigation and weeding were applied during the plant growth period. To measure the plant growth indices like, Leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) leaf area and plant dry weight was measured every two weeks from 30 days after planting dates as described by Gardner et al. (1991).

\[ \text{LAI} = \frac{\text{LA}}{\text{GA}} \]  
\[ \text{CGR} = \frac{1}{\text{GA}} \times \frac{\text{W}_2 - \text{W}_1}{\text{T}_2 - \text{T}_1} \]  
\[ \text{RGR} = \frac{\ln\text{W}_2 - \ln\text{W}_1}{\text{T}_2 - \text{T}_1} \]

W: dry weight, T: sampling time, LA: leaf area, GA: ground area.

To determine the forage yield, stem diameter and leaf number per pant, 10 plants were harvested randomly from each plot and measured. Dry forage yield was measured after drying whole plants in 65° C for 72 h (Mugerwa & Bwabye1974; Rivelli et al., 2008). Analysis of variance of all the traits and comparison of means (by Duncan’s multiple range test) were carried out by MSTAT-C software and the diagrams were drawn by Microsoft Office Excel 2007.

Table 1: Physicochemical properties of Soil collected from the study areas.

| Element | pH  | Ec | Clay | Silt | Sand | N   | P   | K   | Fe  | Zn  | Cu  | Mn  |
|---------|-----|----|------|------|------|-----|-----|-----|-----|-----|-----|-----|
| Rate    | d/s | m  | (%)  |      |      |     |     |     |     |     |     |     |
| Location A | 7.73 | 0.74 | 41   | 45   | 14   | 0.1 | 32.8| 480 | 10.8| 1.3 | 1.03| 9.7 |
| Location B | 7.9  | 0.93 | 39.6 | 44.2 | 16.2 | 0.098 | 18  | 400 | 8.3 | 0.7 | 1.94 | 8.6 |

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3 Results and Discussion

3.1 Stem diameter

Results of study revealed that plant density and planting date had significant effect on stem diameter (Table 2). Further, interactions of plant density and planting date were also reported significant. The highest stem diameter (7.33 cm) was reported from the treatment of July 6th planting date and 6.6 plant.m\(^{-2}\) density (Table 3). While, the lowest stem diameter (2.46 cm) was obtained from the treatments of July 21st planting date and 11 plant.m\(^{-2}\) density. It was reported that stem diameter significantly reduced by increase in plant density from 6.6 plant.m\(^{-2}\) and delay in planting date from July 6th. These results are in agreements with the findings of the Ayub et al. (2003) and Artega et al. (1991). According to Gimplinger (2008) decreases in plant density provided more space per plant and decreases plant competition which increased the growth characteristics especially amaranth stem diameter. Further, Moshaver et al. (2013 a) similarly reported that amaranth plant density and planting date had significant effect on thickness of stem.

3.2 Number of leaves per plant

Analysis of variance result for amaranth leaves number indicated the significant effect of planting date and plant density on amaranth leaves (Table 2). Maximum number of leaves per plant (395 leaves per plant) was obtained from 6.6 plant.m\(^{-2}\) density and planting date July 6th (Table 3). Similar results were observed by Aynehband et al. (2007), these researchers were reported that different planting date had significant effect on qualitative and quantitative performance along with leaf number of amaranth (Aynehband et al., 2007).

Additionally, Henderson et al. (2000) reported that plant density in amaranth could affect the number of leaf per plant. Further, they highlight that in high plant densities, the size of leaf was lower.

3.3 leaf Dry Weight

Leaf dry weight in amaranth was one of the research targets of plant quality. Results of this study suggested that highest leaf dry weight (2075.6kg.ha\(^{-1}\)) was reported from the plant shown on July 6th planting date and 6.6 plant.m\(^{-2}\) density simultaneously (Table3). In a study, Ansariardali & Aghaaliikhani (2013) considered the effect of planting density on qualitative and quantitative performance of amaranth; lower plant density causes the increase the number of leaf and leaf weight in plants.

3.4 Stem dry weight

Plant density and planting date interaction treatments had significant effect on Stem dry weight in both years (Table 2). Like other growth attributes, highest mean stem dry weight (7916.8kg.ha\(^{-1}\)) was gained from July 6th planting date and 6.6 plant.m\(^{-2}\) density too (Table 3). In an investigations on the effect of plant density on qualitative and quantitative performance of amaranth Tucker (1986) reported that amaranth stem had significant effect on the density and high plant density declined the stem diameter, number of leaf and plant height. The recognition of optimal density causes increasing in stem diameter, stem weight and at last dry matter by suitable planting date and providing good seedbed (environmental conditions) of growth and development of shoot of amaranth in optimal temperature. Results of these investigations had compatibility with findings Henderson et al. (2000).
Table 3 Means comparison of interaction effects of density and planting date on investigation traits in two locations.

| Treatments | measured traits |
|------------|----------------|
| Density (Plant.m⁻²) | Planting date | Stem diameter (cm) | no. Leaf per plants | leaf dry weight (kg.ha⁻²) | steam dry weight (kg.ha⁻²) | Dried forage yield (kg.ha⁻²) |
| 6.6 June 22 A | 5.30⁹ | 351.16⁹ | 1748.00⁹ | 3727.00⁹ | 6244.00⁹ |
| B | 5.23⁹ | 335.83⁹ | 1540.60⁹ | 3987.40⁹ | 5915.47⁹ |
| 8.3 June 22 A | 3.96⁹ | 286.33⁹ | 1513.60c | 1517.60⁹ | 4400.63⁹ |
| B | 4.03⁹ | 268.33⁹ | 1492.26⁹ | 3980.80⁹ | 5504.47⁹ |
| 11 June 22 A | 3.40⁹ | 199.60⁹ | 1180.30⁹ | 1307.90⁹ | 3962.60⁹ |
| B | 3.66⁹ | 180.41g | 1739.46⁹ | 2898.50⁹ | 4757.50⁹ |
| 6.6 July 6 A | 7.33⁹ | 391.76⁹ | 2056.00⁹ | 7547.00⁹ | 11279.70⁹ |
| B | 7.00⁹ | 395.00⁹ | 2075.60⁹ | 7916.80⁹ | 11748.80⁹ |
| 8.3 July 6 A | 5.03⁹ | 287.83⁹ | 1762.66⁹ | 4368.00⁹ | 7720.07⁹ |
| B | 5.06⁹ | 281.66⁹ | 1889.33⁹ | 4752.20⁹ | 7339.60⁹ |
| 11 July 6 A | 4.02⁹ | 237.00⁹ | 1218.06⁹ | 4373.60⁹ | 6719.17⁹ |
| B | 4.03⁹ | 207.66⁹ | 1313.03⁹ | 4310.17⁹ | 6272.93⁹ |
| 6.6 July 21 A | 4.58⁹ | 225.00⁹ | 1328.00⁹ | 2952.0⁹ | 4492.87⁹ |
| B | 4.50⁹ | 237.66⁹ | 1204.60⁹ | 3015.6⁹ | 4505.6⁹ |
| 8.3 July 21 A | 3.73⁹ | 111.00⁹ | 1318.66³ | 2762.67⁹ | 4123.90⁹ |
| B | 3.00⁹ | 164.33⁹ | 1012.00⁹ | 2731.47⁹ | 4052.67⁹ |
| 11 July 21 A | 2.65⁹ | 97.66⁹ | 1113.20⁹ | 2503.60⁹ | 3847.90⁹ |
| B | 2.46⁹ | 112.66⁹ | 985.96⁹ | 2209.53⁹ | 3699.6⁹ |

Means in each column followed by similar letter(s) are not significantly different at 5% probability level using Duncan’s Multiple Range Test.

3.5 Dry forage yield

Results of this study suggested that Amaranth forage yield was significantly affected by plant density and planting date at both experimental sites (Table 2). Comparison of forage yield showed that, the highest dry forage yield (11748.80kg.ha⁻¹) was reported from the planting date July 6th and plant densities 6.6 plant.m⁻² while the lowest one (3699.6 kg.ha⁻¹) was reported from the planting date July 21th and plant density 11 plant.m⁻² (Table 3). Dry forage yield reported in this study are similar to the findings of Moshaver et al. (2013 b) those have reported 11279.70 kg.ha⁻¹ forage yields. Similarly, Weber (1987) reported that by increasing density and delaying planting date decreased the dry forage yield of amaranth crops. It was reported that dry forage of amaranth to different density and planting dates shows multiple reactions and at suitable planting date and optimal density increased dry forage yields.

3.6 Leaf Area Index (LAI)

Trends of amaranth leaf area index at different density and planting date Inserted curves were represented in figure 1 (A and B). All treatments had similar trends and showed highest LAI values after 75 days of planting when the last leaf is appeared and flower will start appear at the end of stem.

![Figure 1 Effect of planting dates (A) and plant density (B) on Amaranth leaf area index.](http://www.jebas.org)
In the beginning of growth period, the growth of leaf area index was so low but by spending time not only the plant growth increased but value of LAI also increased and will reach to maximum. In the end of growing season some decline in LAI was also reported. Among various tested planting dates and plant density, maximum LAI was reported at density 6.6 plant m$^{-2}$. Further, it was reported that by increasing the plant density, LAI was declined. Probably, the reason of this affair is suitable distribution of plants, suitable overlapping of leaves and their less shading which causes better usage of environmental factors.

The maximum LAI in July 6th planting date and the least LAI observed in July 21st planting date. Murua (2002) was reported that effects of planting date is correlated with the temperature and ultimately affect the number of leaves and development of plant covering. Temperature can increases the speed of leaves appearance but necessarily it does not guarantee the increases the leaf surface and its durability (Nourmohamadi et al., 2002). Suitable LAI not only increased the speed of product synthesis but also had significant effect on the rate of photosynthesis, production of higher matter and on performance. By delaying planting date, senescence and defoliation of leaves happened faster and on the other hand because of the length of growth period, the time of expanding leaves surface is less and at last LAI is declined (Azizi & Mahrokh, 2007).

3.7 Crop Growth Rate (CGR)

Figure 2 shows that speed of crop growth at different plant density and planting date in amaranth. In the first stages of growth, the value of crop growth is low but by spending time, rate of crop growth started increasing. Values of crop growth were highest at the time of flowering. The highest speed of crop growth was observed in plant density of 6.6 plant m$^{-2}$ at July 6th planting date (Figure 2). On the other hand increasing density declined the speed of crop growth. High plant density increasing shading in plant and limited the rate of light absorption which could finally affected the plant growth and performance. Increasing plant density causes increasing plants competition and at last limiting the availability of food elements and declining CGR (Shumway et al., 1992). In general high speed of crop growth means aggregation of high dry matter and more performance. Therefore treatment which has more speed of crop growth and it has the performance of more forage (Moghimi & Emam, 2012).
3.8 Relative Growth Rate (RGR)

Figure 3 showing that by increasing plant age, relative growth rate started declined linearly. As observed for other growth attributes, maximum relative growth rate was observed in 6.6 plant m\(^{-2}\) density at July 6\(^{th}\) planting date. Since by increasing plant age, adds on structure tissue of plant which these structure tissue have no share in growth, relative growth rate will be negative during the time and increasing breath at the last season of growth (Pandey et al., 2000). It was reported by many researchers that relative growth rate of crop will declined through growth season by shading arising plant density and by delaying planting date and increasing temperature and the severity of breathing (Eddowes, 1969; Bueno & Atkins, 1982). Azizi & Mahrokh (2007) reported in their studies on corn that increasing density causes declining growth indices such as RGR.

**Conclusion**

In general, the results of this study showed that, the amaranth plant is very sensitive to planting date and plant density as well. The effect of planting date and plant densities could be most effectiveness on forage yield, leaf numbers, dry weight and also, trends in growth indices significantly. With this paper we try to highlight that the right range for plant density and planting date in every environment condition with producing high crop yield and sharp growth indices are accompanied emphatically.

**Conflict of interest**

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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