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Plant Population Influence on Yield and Agronomic Traits in 'Plainsman' Grain Amaranth*

F.R. Guillen-Portal, D.D. Baltensperger, and L.A. Nelson

Grain amaranth, a pseudo-cereal with a rich history as a source of food in Meso America, is an attractive alternative crop suitable to be produced in semi-arid conditions. Grain amaranth production in the United States was 1,800 ha in 1991 (Stallknecht and Schulz-Schaeffer 1991). Most amaranth production is located in the Great Plains, especially in Western Nebraska (Williams and Brenner 1995), a semi-arid region with an average annual precipitation of less than 400 mm. Under these conditions, 'Plainsman' is the most widely grown grain amaranth cultivar. Grain yields range from 800 to 1100 kg/ha (Baltensperger et al. 1991; Myers 1994).

Currently, there is no commercially available planting equipment for amaranth because of its unusually small seed size (two million seeds/kg). Adapting existing planters for other crops has become a practical solution for the growers. The lowest seeding rate at present is about 1 kg seed/ha. Observations in the field indicates that 2 million plants/ha may be too high. In other crops, reduced grain yield, increased lodging, and lack of plant vigor are problems associated with excessively high plant populations.

Previous research conducted on grain amaranth suggests that yield is maximized at low plant populations (60,000 to 75,000 plants/ha) (Duncan and Volak 1979; Mnzava and Ntimbwa 1985; Henderson et al. 1991). However, most of these studies dealt with non-uniform landrace populations or with evaluations under wider row spacings. Identification of plant populations that maximize grain yields in improved cultivars is still an aspect that requires attention. Information obtained from these studies might be useful for the design of equipment capable of seeding more appropriate plant populations. The objective of this study was to evaluate the effect of plant population on grain yield and some agronomic components of 'Plainsman' grain amaranth.

METHODOLOGY

A dryland study was conducted at the University of Nebraska Panhandle Research and Extension Center at Scottsbluff, NE and at the High Plains Agricultural Laboratory near Sidney, NE in 1991 and 1992. 'Plainsman' grain amaranth (*A. hypochondriacus* × *A. hybridus*) (Baltensperger et al. 1992) was planted at Scottsbluff on 16 June 1991 and 21 June 1992 in an Otero loam (Tripp very fine sandy loam) soil. At Sidney, planting was on 24 June 1991 and 22 June 1992 on a Duroc loam (fine-silty, mixed, mesic, Pachic Haplustoll) soil. Ammonium nitrate was applied pre-plant at a rate of 100 kg N/ha. Plots were hand-weeded. The experiment was arranged as a randomized complete block design with plant populations of 2 M (million) (control), 1.4 M, 0.7 M, 0.35 M, 0.17 M, 0.085 M, and 0.043 M plants/ha with four replications at each location and year. Populations were established by over-planting and hand thinning the seedlings three weeks after planting to the appropriate plant spacing. Plots were four 76 cm rows wide and 4 m long in the experiments at Scottsbluff and 6 m long at Sidney. Measurements taken at maturity (100 days after planting) from 10 plants randomly chosen in each plot were plant height (measured from the ground to the top of the inflorescence head), inflorescence length (measured from the base to the top), and stem diameter (measured in the main stem at two thirds of the height above). Lodging percentage was determined on a plot basis before harvesting. Grain yield was obtained from the center two rows in each plot. Data from the experiments were analyzed using Statistical Analysis System (SAS Institute, Inc. 1989). For the analyses of variance, plant population was considered as fixed and blocks as random effects. For the combined analysis of variance, all effects except plant population were considered random. Consequently, the environment × plant population interaction effect was used as an error term for testing differences among plant populations. Plant population effect was partitioned using linear and quadratic orthogonal contrasts to identify the nature of the response. Additionally, linear orthogonal contrasts were used to compare means among treatments.

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EXPERIMENTAL RESULTS

Conditions were extremely dry at Scottsbluff in 1991 but precipitation was near normal in 1992. Above-average moisture conditions were prevalent in the Sidney area in 1992 but precipitation was below normal in 1991. Growing season temperature at both locations was warm in 1991 and cooler in 1992 (data not shown). As a result of an early freeze at Scottsbluff in 1991, grain yield at maturity was substantially low (34 kg/ha) compared to normal yields (> 400 kg/ha). Also, grain yield at the 1992 Scottsbluff experiment was not collected because of a hailstorm which destroyed the field plots during the last week of August. Therefore, grain yield for these experiments were not included in the analysis.

At Sidney in 1991, significant differences in grain yield among plant populations were found (data not shown). Populations of 0.043 M, 1.4 M and 2 M plants/ha were different for grain yield but populations between 0.085 M and 0.7 M plants/ha produced similar grain yield. In the 1992 Sidney experiment, no significant yield differences among plant populations were observed.

A combined analysis of grain yield over environments showed significant differences between environments and plant populations. Differences in grain yield might be attributable in part to changes in the environmental conditions during the growing seasons of 1991 and 1992. For the range of populations studied, there was a significant quadratic response for grain yield (data not shown). A regression analysis of plant population on grain yield (Fig. 1) showed that grain yield reached its maximum (1050 kg/ha) at a population of about 0.47 M plants/ha, although the increase in grain yield at this population is only 2% compared to the overall mean (1023 kg/ha). The response of grain yield at populations in the range between 0.043 M and 0.95 M plants/ha was above the overall mean. Increase in grain yield at populations from 0.043 M to 0.47 M plants/ha suggests that little interplant competition occurs in this range. Decrease in grain yield at populations higher than 0.47 M plants/ha might be attributable to interplant competition. A linear contrast analysis showed the response of grain yield was higher at the lowest populations (0.043 M and 0.085 M plants/ha) and it was lower at the highest populations (1.4 M and 2 M plants/ha).

No significant differences in plant height among plant populations were observed in the experiment at Scottsbluff in 1991. Contrastingly, it was significant at Sidney. In 1991 at Sidney, plants at the lower populations were significantly taller than at the higher populations, and plants at the control population were significantly shorter than the other populations. No differences in plant height at populations between 0.085 M and 0.7 M plants/ha were observed. However, at Sidney in 1992 the highest population was significantly taller

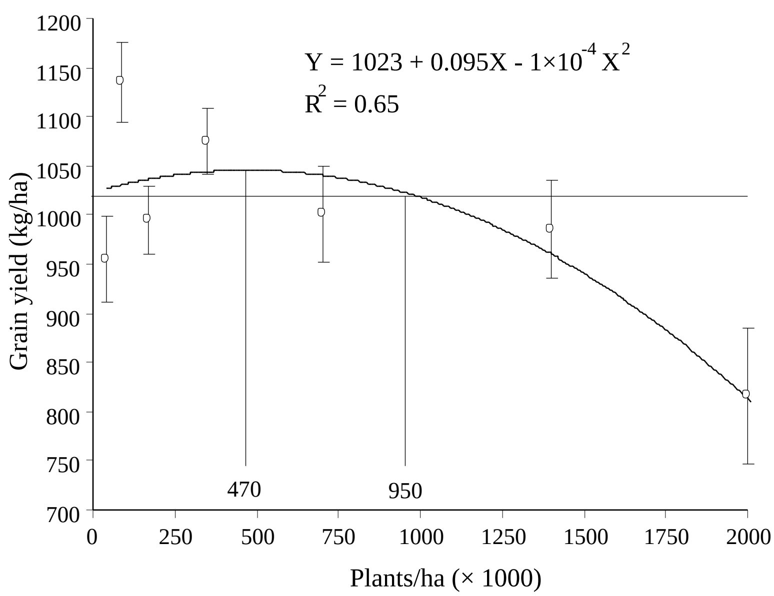

Fig. 1. Regression of plant population on grain yield (kg/ha) in 'Plainsman' grain amaranth. Sidney, Nebraska, 1991, 1992.

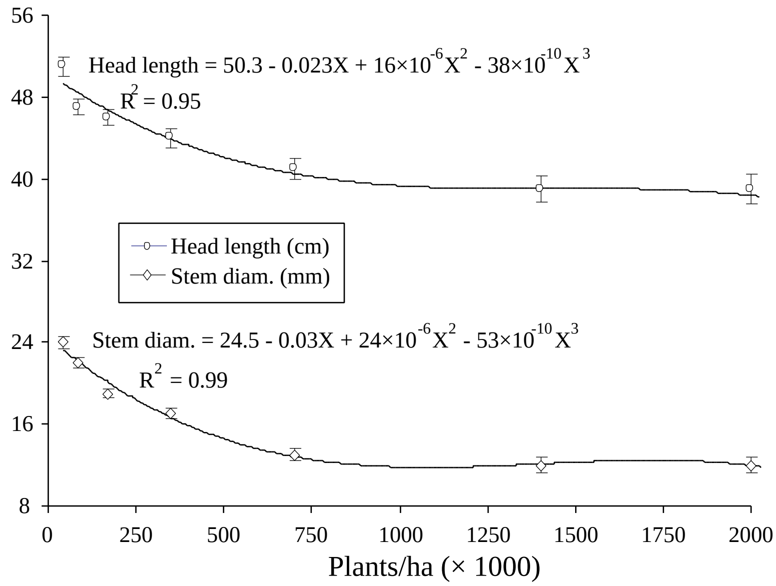

Fig. 2. Regression of plant population on seed-head length (cm) and stem diameter (mm) in 'Plainsman' grain amaranth. Sidney and Scottsbluff, Nebraska, 1991, 1992.

than the other populations. In general, plants at the low populations were significantly shorter (data not shown). Since conditions at Sidney in 1991 and 1992 were highly variable in precipitation, it can be inferred that the effect of plant population on plant height is substantially dependent on soil water availability. Combined over years and locations, plant height was unaffected by plant population (data not shown). The lack of response of plant height to a wide range of plant populations over environments may be the result of the ability of the crop to compensate for environmental factors by minimizing competition for water and light.

Seed head length response to plant population was significant at Scottsbluff in 1991. At this location seed head length reached its maximum at the lowest population. No significance for seed-head length among plant populations was found at Sidney. Combined over years and locations, the effect of plant population on seed head length was highly significant showing a cubic response and the same pattern at all environments (no environment × plant population interaction) (data not shown). Seed head length reached its maximum at the lowest plant population and then declined as plant population increased (Fig. 2). It is evident that grain yield was maintained at lower populations by an increase in seed head length and was decreased at higher populations as a result of interplant competition.

Stem diameter was greatly affected by plant population (data not shown). Consistently among locations and combined over locations stem diameter showed a cubic response to plant population (Fig. 2). In general, plants exhibited a robust main stem at low populations decreasing at higher populations. The decrease in stem diameter with increasing plant population may be the result of water and light interplant competition. The lack of response of plant height, the large change in stem diameter, and the modest response of grain yield to plant population suggests that grain amaranth compensates for a high plant population by translocating reserve assimilates from the stem to the reproductive organs. This is in agreement with the results obtained by Hauptli (1977), who found in a cultivated form of *Amaranthus* spp. a negative correlation between seed yield per plant and allocation of energy to stem.

Total lodging was unaffected by plant population at any of the locations and years. The highest lodging rates corresponded to populations between 0.085 M and 0.35 M plants/ha (data not shown). It is important to note, however, that at low populations peduncle lodging was observed, whereas at high densities stalk lodging was prevalent.

CONCLUSION

The modest response of grain yield to a wide range of plant populations may be interpreted as the ability of the amaranth to compensate for environmental variations through a) allocation of more energy to reproductive organs in the plant at the expense of a restriction in stem diameter, and b) minimizing the effects of water and solar radiation competition. Grain yield above the overall mean was obtained at a plant population in the range between 0.043 M and 0.95 M plants/ha. Considering this study as an initial step, further studies including other improved grain amaranth cultivars need to be conducted with the ultimate goal of providing information for the design and development of equipment and techniques for planting grain amaranth for rain-fed areas.

REFERENCES

Baltensperger, D.D., D.J. Lyon, L.A. Nelson, and A. Corr. 1991. Amaranth grain production in Nebraska. NF 91-35. Univ. Nebraska–Lincoln.

Baltensperger, D.D., L.E. Weber, and L.A. Nelson. 1992. Registration of 'Plainsman' grain amaranth. Crop Sci. 32:1510–1511.

Duncan, A. and B. Volak. 1979. Grain amaranth: Optimization of field population density. In: Proc. 2nd. Amaranth Seminar; July 29, 1979. Maxatawny, PA.

Hauptli, H. 1977. Agronomic potential and breeding strategy for grain amaranths. p. 71–78. In: Proc. 1st. Amaranth Sem., Rodale Press, Emmaus, PA.

Henderson, T.L., A.A. Schneiter, and N. Riveland. 1991. Row spacing and population effects on yield of grain amaranth in North Dakota. p. 219–221. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York.

Mnzava, N.A. and T. Ntimbwa. 1985. Influence of plant density on edible leaf and seed yields of vegetable amaranth following repeated leaf harvest. Acta Hort. 158:127–132.

Myers, R.L. 1994. Regional amaranth variety test. Legacy. The Official Newsletter of the Amaranth Institute. Vol. VII. No. 1

SAS Institute Inc., SAS/STAT. 1989. User's guide version 6, 4th ed. Vol. 2, SAS Institute Inc., Cary, NC.

Stallknecht, G.F. and J.R. Schulz-Schaeffer. 1991. Amaranth rediscovered. p. 211–218. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York.

Williams, J.T. and D. Brenner. 1995. Grain amaranth (*Amaranthus* species). p 129–186. In: J.T. Williams (ed.), Cereals and pseudocereals. Chapman and Hall, London.