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Evaluation of Amaranth Production Possibility in Arid and Semi Arid Regions of Iran

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Abstract: In order to study the possibility of amaranth cultivation in arid and semi arid regions of Iran, in respect to yield production, a case study was conducted at the Abourayhan campus (a branch of Tehran University); located at Pakdasht area of Varamin as an arid and semi-arid area. This experiment was done on 16 amaranth genotypes in growing season of 2001-2002 to evaluate yield, yield components and protein contents of grains. Present results indicated that grain yield varied from 3.445 to 2.265 t ha^{-1} for *Amaranthus cruentus,* while these values varied from 1.385 to 1.945 t ha^{-1} for *Amaranthus hypochondriacus* (mean values were 2.95 and 1.65 t ha^{-1} for *A. cruentus* and *A. hypochondriacus*, respectively). Putting these results with obtained yields showed an average yield of 2000 kg ha^{-1}. Higher mean 1000 grain weight (68.47 versus 58 g), harvest index (55.16 versus 33.4%) and total dry weight percentage (46.9 versus 38.2%) for *A. cruentus* resulted in higher grain yield than *A. hypochondriacus*, while A. *hypochondriacus* genotypes showed higher protein content than *A. cruentus* (mean values of 15.7 and 14.43%, respectively). it concluded that amaranth species (especially *A. cruentus* spp.) could be cultivated successfully in arid and semi arid regions, if we select appropriate genotypes and the best agronomic options to achieve higher yields. This crop can be investigated as a new crop to extend arable marginal lands and sustaining the agricultural systems of stressful environments.

Key words: Amaranth, production, yield components, protein content, arid and semiarid regions

INTRODUCTION

Humans being in Asia and southern American regions during last centuries cultivate amaranth. Peru, Mexico, and Ecuador have been the South American origins of amaranth, while it is also cultivated in India (half of dry land cultivations of north India (National Research Council, 1994) and China (FAO, 1999). Both Quinoa (Chenopodium quinoa) and amaranth belong to pseudo cereals that in spite of botanical differences have similar development as cereal grains. Amaranth is interesting as an additional substance in human foods. The grain and leaves of amaranth can also use as a valuable food source for humans and feeding of animals (Dobos, 1992), because of its high protein content and quality (Aufhammer *et al*., 1995; Elbehri *et al*., 1993), considerable amounts of unsaturated fatty acids in grains (Aufhammer and Kübler, 1998), raw fiber and higher amounts of some minerals like Ca, Mg and Fe in comparison with other cereals. Therefore amaranth can be considered as a supplementary protein source to alleviate protein deficiency in developing countries, caused by one-way utilization of carbohydrate sources, as a mixture of high Lysin dough of pseudo cereals and poor dough of maize and rice (Aufhammer *et al*., 1999). It seems that amaranth can have an important role to provide food and food security in the world. In an American study of national academy to fight against world hunger that was conducted on many hundreds of species to be cultivated, amaranth was selected and recommended in companion with 22 other species to cultivate (National Research Council, 1994).

One of other advantages of amaranth is its tolerance to drought and adaptability to marginal and less fertile soils to increase farmer's income and improving food security. Low water requirement of amaranth (high water use efficiency), (Burton and Henderson, 2002) to produce dry matter as a C4 plant (230 L Kg^{-1}) and negative response to excessive water supply during growing season (unfavorable branching) are the cause of importance of this plant to recommend that as an alternative or new plant in agricultural systems of arid and semi-arid regions of Iran, as it has recommended as a foundation for improving the income and nourishing situation of peoples of such regions in other literatures (Dobos, 1992; Gupta *et al*., 1994). Also, base temperature of emergence of amaranth is so high that caused clear susceptibility of that to frost and this is one of other

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adaptations of this plant to semi-arid regions (Fleming and Galwey, 1995; Kruse, 1996). This study aimed to investigate the opportunities and challenges of the cultivation of grain amaranth in semi-arid regions of Iran (a case study in Varamin) and comprise of many important characters related to yield in different genotypes.

The opportunities and challenges to improve cultivation of amaranth species in Iran: The increasing need to provide food security of forth growing population of world makes it necessary to think about different aspects of utilization of unused species and considering them in our development programs for future.

The international research communications speak about new crops and pseudo cereals (including amaranth species) can be considered and used in this regard. Intensive farming of crops as monocultures or decreased diversity farms with a few species and successive and tight cultivation of them in rotations generally increases the risk of pathogens. Therefore, considering of these kinds of crops in addition to increase biodiversity of agro ecosystems, can provide new options for design new and reasonable rotation scenarios and consequently will cause stability of these systems. Also, these crops can improve the nourishing situation of peoples, which subjected to protein deficiency in developing countries (as Iran) with one-sided carbohydrate nutrition. On the other hand, aesthetical aspects that are so important in landscape ecology should not be ignored.

Following considerations and facts can be summarized and mentioned directly or indirectly in this study in Iran, as the cultivation of amaranth in Iran:

- Will increase variability and quality of nutrients
- Will increase the income of exports
- Will provide the possibility of designing better and more economically rotations and increasing productions relief
- Can be considered as an alternative drought resistant crop in the regions subjected to limited rainfall to increase arable lands surface

In addition to above-mentioned cases, its high price is another advantage for amaranth, as a part of costs can be covered by it.

The variability of history and differently spreading of amaranth species all over the world allow only general considerations to its possible importance in future in Iran, because regional estimation of validity of each crop is so complicated, caused by complete different reasons.

But the question is whether it is reasonable that the researches, improvements and cultivation of main crops, which provide the nutrients for human to be set aside and focus the investigation on limited species? It is asked what the consequences are of to take this action and what happens for the remaining species? Of course, the plant species as a part of ecosystem cannot be evaluated separately.

There are enough reasons to direct all our investigations in all aspects of new crops, but the correlation between changing of land utilization and losing processes of remaining species shouldn’t be ignored.

MATERIALS AND METHODS

An experiment was conducted at the Pardis of Tehran University (Abourayhan branch) located at Pakdasht area of Varamin (53°28` N, 50°581 E and 1180 m above sea level), Iran, in the growing season of 2001-2002. The soil included clay (32%), loam (39.2%) and sand (29.2%). Sixteen genotypes of amaranth (Table 1) were used in this study. The genotypes were sown in a Randomized Complete Blocks Design with four replications. Plots were hand seeded from 16 to 20 march, using row spacing of 45 cm and seeding rate of 1 kg ha^{-1}. Target plant density after rouging was 25 plant m^{-2}. All plots were harvested from 19 July to 3 August 2003. Plant samples were taken from three rows of each plot (each plot included 5 rows). The number of sampling was 2 and sampling involved 5.4 m^2 of total plot area (11.25 m^2). The harvested individual plants by hand, were spread out to dry in open conditions and ultimately were threshed, cleaned and dried in appropriate conditions.

Finally, 16 used amaranth genotypes were compared for some characteristics such as yield, 1000-grain weight, harvest index, and plant height. Statistical analysis was done by VOA and mean comparisons were made using LSD procedure at 1% level of probability.

Table 1: Studied genotypes and some additional descriptions about their characteristics

Name	Species	Origin
Amont	*Amaranthus cruentus*	USA
MT 3	*Amaranthus cruentus*	USA
Nu World	*Amaranthus cruentus*	USA
MT-3	*Amaranthus cruentus*	USA
MT-5	*Amaranthus cruentus*	USA
K266	*Amaranthus cruentus*	USA
A 10	*Amaranthus cruentus*	China
C4	*Amaranthus cruentus*	China
C6	*Amaranthus cruentus*	China
Suvarna	*Amaranthus cruentus*	India
Villarica	*Amaranthus cruentus*	South America
Puerto M.	*Amaranthus cruentus*	South America
Anden	*Amaranthus cruentus*	South America
N 2037	*Amaranthus hypochondriacus*	Japan
N 2043	*Amaranthus hypochondriacus*	Japan
N 2048	*Amaranthus hypochondriacus*	Japan

Table 2: Combined analysis of variance for two years data

Source	df	Yield (t ha^{-1})	Seed weight (%)	1000 KW	Protein	Harvest index	Plant height (cm)
Year	1	0.435**	175.3**	0.384ns	7.595**	59.071**	183.386**
Error	4	0.009	6.299	2.733	0.309	0.854	0.685
Genotype	15	2.146**	164.814**	361.467**	3.996**	591.032**	1004.802**
Yield x Genotype	15	0.086**	5.962**	16.539**	0.739**	8.441**	4.477**
Error	60	0.007.	1.059	0.161	0.021	0.561	0.385
CV%		4.7	5.9	2.6	3.8	2.4	1.1

** = Significant at 1%, ns = non significant

RESULTS AND DISCUSSION

Mean value comparisons for grain yield (Table 4) showed that the genotypes No. 1, 3, 6 and 11 had the highest grain yield, respectively. Also, the genotypes No. 3, 6 and 11 had higher yield in combined analysis of grain yield for 2 years in comparison with separate analysis for each year (Table 2 and 3). Mean values for grain yield of all genotypes of *A. cruentus* and *A. hypchondriacus* were 2.95±0.33 and 1.65±0.22 g, respectively. The genotype No. 1 (Amont, belonged to *A. cruentus*) was the best one regarding to grain yield (3445 kg ha^{-1}), that was so higher than reported mean grain yield of 2000 kg ha^{-1} for amaranth by Aufhammer (2000). Comparisons indicated that the lowest yield was belonged to the genotype No. 16 (Belonged to *A. hypchondriacus* spp.). Present results demonstrated that the mean grain yield of the genotypes of *A. hypchondriacus* was about 45% lesser than the *A. cruentus* genotypes. Mean value comparisons of total dry weight between studied genotypes indicated the highest values for genotypes No. 3-9 (All belonged to *A. cruentus*). The highest dry weight percentage belonged to the genotypes No. 7 and 8 (50.9 and 51.8%, respectively) and first year experiment (2001), while the lowest one belonged to the genotypes No. 14 and 16 (belonged to *A. hypochondriacus*), as 33.9 and 34.3%, respectively

Also, results indicated that harvest indices (percentage of seeds in dried fruit organ) of *A. cruentus* genotypes were higher than *A. hypochondriacus* genotypes (Table 4), as the highest values for harvest index belonged to the genotypes No. 3 and 4 (58.8 and 57.6%) and lowest one belonged to the genotype No. 14 (25.3%). Mean values of harvest index for *A. cruentus* and *A. hypochondriacus* also were significantly different (55.16 and 33.4%, respectively).

The highest thousand-grain weight was also seen in two genotypes of *A. cruentus* (The genotypes No. 8 and 9) with 0.78 and 0.77 g, respectively (Table 5). In general, the thousand grain weight of genotypes of *A. hypochondriacus* was less than genotypes of *A. cruentus*, as the lowest grain weight was related to the genotype No. 15. Mean values of thousand grain weight were 68.5 and 58 g for *A. cruentus* and *A. hypochondriacus*, respectively.

Table 3: Dispersion of mean year dependent variables

	Year	Mean	F-values
Yield (t/ha)	2001	2.611	48.3**
	2002	2.746	
Seed weight%	2001	46.6	27.8**
	2002	43.9	
1000 K.W.	2001	66.2	0.2ns
	2002	66.1	
Protein	2001	15	24.6**
	2002	14.4	
Harvest index	2001	50.3	70.3**
	2002	51.8	
Plant height (cm)	2001	104	267.7**
	2002	108.8	

** = Significant at 1%, ns = non significant

Protein content analysis demonstrated the higher protein content of *A. hypochondriacus* than *A. cruentus* spp. the highest values were seen in genotypes No 14 and 15 (15.8 and 16%, respectively). Measured protein contents in different studied genotypes varied between 12 to 16%, depend on N-supply of soil, but differences were not considerable between different genotypes (mean values for all genotypes of *A. cruentus* and *A. hypochondriacus* were 14.43 and 15.7%, respectively).

Gupta *et al.* (1994) achieved grain yield of 300-700 and 1700 Kg ha^{-1} under unfavorable conditions and optimized cultivation date, respectively in Kenya. The other reports by Espitia (1992), 1500-3200 kg ha in Mexico and Sumar (1992), 1500-3000 kg ha for unproved local varieties originated from Peru, with Growing period of 177 and 206 days are other examples to show ability of amaranth to yield production. The highest reported grain yield of amaranth belongs to a Rodale Research Center Source Originated Variety with 5341 kg ha^{-1} in USA (Schulz-Schaffer *et al.*, 1989).

Joshi and Rana (1991) reported more but Wehinger (1993) found less protein content in *A. hypochondriacus* in comparison with *A. cruentus*, that the last one is consistent with the results of this study about protein content. The grains of amaranth contain 13-17% protein (N×5.85), it doesn't seem to be profitable to have higher protein content, but at the other side it is a good selling argument to expand a cultivar.

The out yielding of *A. cruentus* was due to its reliable yield, caused by a rash development. Although

Table 4: Means comparisons of different traits in different genotypes

Genotype	Yield (t ha^{-1})	Grain weight (%)	1000 KW	Protein (%)	Harvest index (%)	Plant height (cm)
1	3.445a	45.7cd	68.5d	14.0gh	57.4a-c	105.1e
2	3.067b	40.8e	66.5e	13.5e	53.7f	107.9d
3	3.283a	49.2ab	67.5e	13.7he	58.8a	104.8e
4	2.974bc	48.1abc	64.9f	14.3fg	57.6ab	96.7g
5	2.862cd	49.2ab	69.4d	14.8de	55.7c-e	113.4c
6	3.228abc	49.0ab	73.1e	14.2gh	57.4a-c	111.7c
7	3.044bc	50.4a	75.9b	13.7gh	55.8c-e	116.2b
8	3.047bc	48.7ab	77.8a	14.1gh	56.6b-d	98.8f
9	2.763d	48.5ab	77.2a	14.2gh	55.1d-f	117.2b
10	2.914bcd	47.7bc	69.7d	14.8ef	54.3ef	109.5d
11	3.253abc	46.0cd	62.8g	15.1cde	56.2b-d	87.5i
12	2.285e	47.0bcd	59.3h	15.6abc	54.7ef	91.7h
13	2.277e	39.8e	57.5i	15.6abc	43.9g	116.2b
14	1.623g	33.9f	59.9h	15.8ab	25.3h	120.8a
15	1.945f	46.6e	49.0j	16.0a	43.2g	73.1j
16	1.387h	34.3f	65.1f	15.3bcd	31.7h	115.8b

Means with the same letters in each column are not significantly different at 5% level of probability

Table 5: Means comparisons of studied traits in different genotypes and years (combined analysis)

Genotype	Year	Yield (t ha^{-1})	Seed weight (%)	1000 KW	Protein (%)	Harvest index	Plant height (cm)
1	2001	3.419a	46.2h-k	67.7de	14.2i-l	58.2ab	105.2j
	2002	3.471a	45.3j-l	68.3d	13.8k-m	56.5b-f	105.0jk
2	2001	2.875f-h	42.5mm	65.5fgh	14.5g-h	52.7hi	107.2h-j
	2002	3.260a-c	39.0o	67.5d-f	12.4o	54.8d-h	108.7g-I
3	2001	3.150c-e	50.3a-c	66.3e-g	14.2i-l	58.1ab	102.7kl
	2002	3.417ab	48.1e-g	68.7d	13.3mm	59.5a	106.9ij
4	2001	3.081c-f	50.2a-d	65.1gh	14.5g-j	57.3bc	94.8op
	2002	2.867f-h	46.0h-k	64.8gh	14.1j-l	58.0ab	98.6mn
5	2001	2.912e-h	50.6ab	71.2c	14.6g-j	56.7b-e	113.1f
	2002	2.812g-I	47.8f-h	67.5d-f	15.1e-g	54.7e-h	113.7ef
6	2001	2.990d-h	50.4a-c	73.5b	14.7f-i	57.3bc	109.3gh
	2002	3.465a	47.7f-h	72.7bc	13.6lm	57.5a-c	114.2def
7	2001	2.888e-h	50.9ab	74.5b	14.7f-i	54.3f-I	114.0def
	2002	3.201b-d	49.9b-e	77.3a	12.8b-d	57.3bc	118.3bc
8	2001	2.904e-h	51.8a	77.4a	14.4h-k	55.4c-f	97.0no
	2002	3.190b-d	45.7I-k	78.2a	13.9k-m	57.9ab	100.7lm
9	2001	2.750hi	48.7c-f	77.4a	14.6g-j	54.6e-h	115.0def
	2002	2.777hi	48.3c-f	77.0a	13.9k-m	55.5c-f	119.4ab
10	2001	2.978d-h	50.7ab	70.8c	14.5g-j	55.6c-f	109.0g-i
	2002	2.850f-h	44.7kl	68.5d	15.0e-g	52.9g-I	110.0g
11	2001	3.053c-g	48.4d-g	61.6i	15.2c-e	55.0d-g	85.8r
	2002	3.454a	43.7lm	64.0h	14.9e-h	57.4bc	89.3q
12	2001	2.106k	47.3f-I	58.0kl	15.7bc	52.3j	90.0q
	2002	2.464j	46.7g-j	60.6ij	15.4b-d	57.0b-d	93.4p
13	2001	1.970kj	41.2n	56.9l	15.7bc	40.8m	116.0c-e
	2002	2.583ij	38.3o	58.2kl	15.5b-d	47.0k	116.3cd
14	2001	1.469m	34.0p	59.0jk	15.9ab	23.9q	120.0ab
	2002	1.777l	33.9p	60.8ij	15.7bc	26.7p	121.7a
15	2001	1.941kl	47.1f-j	50.6m	16.4a	41.6m	72.0s
	2002	1.950ki	46.1h-k	47.4n	15.7bc	44.8l	74.2s
16	2001	1.296m	34.6p	63.9h	15.5b-d	30.3o	113.3f
	2002	1.479l	33.9p	66.3e-g	15.1j-l	33.1n	118.3bc

Means with the same letters in each column are not significantly different at 5% level of probability

A. hypchondriacus had clearly a better primary development than *A. cruentus*, but flowered 2 weeks earlier than *A. cruentus* and followed a clearly slower development of fruit-organ after later flowering, which was due to envisage to long days. This observation confirmed the effect of day length on flowering of *A. hypchondriacus*, because amaranth is a short day crop (Kaul *et al.*, 1996). Also lower harvest index for *A. hypchondriacus*, resulted from significant differences of grain weight between *A. hypchondriacus* and *A. cruentus*. Comparing the investigated factors between the genotypes of *A. Cruentus* in 2001 and 2002 revealed that he yields changed from 3.445 to 2.265 t ha^{-1}, while the yields of *A. hypochondriacus* were clearly less and changed from 1.945 to 1.387 t ha^{-1}, which can be related to slower grain filling rate and shorter vegetative growth period (early flowering), as discussed earlier. Also, morphological differences, which were appeared 3-5 weeks after seeding, could be a source of these differences. *A. hypchondriacus* had shiny and slightly curled leaves concentrated on top of the plant, while *A. cruentus* leaves were fewer, but faint and smooth and were distributed along the stem. The canopy structure and leaf shape and color in *A. cruentus* caused more favorable situation to light caption during longer vegetative growth period and consequently higher yield production.

Putting these results with experiences obtained from cultivation, so it comes to an average yield of over 2000 kg ha^{-1} for all genotypes of both species. This mean value for total yield of amaranth genotypes was comprisable with other reports by other researchers (Espitia, 1992; Sumar, 1992). Also, results revealed that The *A. cruentus* spp. had more reliable yield, adaptability and tolerance to drought in both yearly experiments in respect to yield production. Therefore, it can be concluded that amaranth species (especially *A. cruentus* spp) could be cultivated successfully in arid and semi arid regions, if we select appropriate genotypes and the best agronomic options to achieve higher yields. This crop can be investigated as a new crop to extend arable marginal lands and sustaining the agricultural systems of stressful environments.

Totally, to reply to this questions that whether amaranth can be considered as an opportunity crop in agricultural production systems of arid and semi-arid regions of Iran or not? And whether this new crop can be brought closer to consumers or not? Can say Undoubtedly, achievement of high yields in Iran to prepare financial security of farmers need to more multidisciplinary investments on these new crops and infrastructure activities on some aspects such as mechanical harvesting, drying chambers (with proper capacity for harvested grains), proper cleaning processes, and etc. In general in addition to working on protein content, investigation on other factors like genotypes, fertilization, regions, and their relations also are advisable.

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