GAU Res. J., **34** (1) : 37-43 (2009)

Response of grain amaranth (*Amaranthus hypochodriacus* L.) to nitrogen management under moisture stress conditions

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Abstract

An experiment was conducted at Regional Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *rabi* season of two consecutive years 2004-05 and 2005-06 to study the "Nitrogen management with bio-fertilizers in grain amaranth (*Amaranthus hypochondriacus* L.) under different moisture stress" on sandy loam soils. The experiment comprising three treatments of moisture stress viz., no moisture stress, stress at active vegetative stage and stress at active vegetative as well as grain filling stage, and seven treatments of nitrogen management viz., No nitrogen, N_{40} , N_{40} + Azotobacter liquid, N_{40}+ Azotobacter powder, N_{60}, N_{60}+Azotobacter liquid and N_{60}+Azotobacter powder. Results revealed that treatment no moisture stress produced 16.58 and 22.07 per cent higher grain yield over moisture stress at active vegetative stage and stress at active vegetative as well as grain filling stage, respectively in pooled data. For stover yield, moisture stress at active vegetative stage performed better than and stress at active vegetative and grain filling stage in pooled data. Adequate moisture supply led to improve nitrogen and calcium content in grain. Maximum uptake of nitrogen and phosphorus by the crop was observed with no moisture stress followed by moisture stress at active vegetative stage. Among the nitrogen management treatments, N_{60} integrating seed inoculation with Azotobacter liquid culture brought remarkable improvement in stem thickness, length of main inflorescence, number of lateral spikelets and 1000 seeds weight which ultimately reflected in increase in grain and stover yields. It gave 12.39, 45.88 and 223.27 per cent higher grain yield over 60 kg N/ha, N_{40} and no nitrogen, respectively in pooled data. Increase in N levels helped to increase in protein and nitrogen content in grain. However, higher dose of N supplemented with Azotobacter liquid led to maximizing nitrogen content in grain. Azotobacter integration with N aided to enhanced calcium and iron content in grain over respective N alone treatments. N_{60} integrating seed inoculation with Azotobacter liquid culture recorded maximum uptake of nitrogen and phosphorus by the crop.

Key words: Grain amaranth, nitrogen, moisture stress

Introduction

Grain amaranth (*Amaranthus hypochondriacus* L.) is a potential upcoming subsidiary food crop, considered by many as crop of the future. Certain attributes, like higher productivity potential added with substantial quantities of minerals, carbohydrates, fats and proteins are comparable with any other improved cereals. Water scarcity warrants for efficient and economic use of irrigation water in agriculture. Selection of low water requiring crop is one way but increasing production per unit volume of water application need to be taken in to account with minimum losses. Application of irrigation water at critical growth stages without significant reduction in yield is also one of the approaches for water scarce areas. Among the agronomic factors known to augment crop yield, fertilizer management assumes its own contribution. Among three major plant nutrients, nitrogen plays an important role in the synthesis of chlorophyll as well as amino acids, which form building units of protein and thus contribute to the growth of the plant. Nitrogenous fertilizers therefore, form a basic input for getting higher yield.

The increasing cost of fertilizers play a significant role in increasing cost of production of the agricultural produce and thereby reduction in the profit. Further substitution of chemical fertilizers with bio-fertilizers, which are cost effective and eco-friendly, is the way

out for saving nitrogenous fertilizers. Bio-fertilizers harness atmospheric nitrogen with the help of special soil microorganisms, which are either free living in soil or symbiotic with plant and directly or indirectly contribute towards the nitrogen requirement of the plant. Recently, interest has aroused to produce liquid bio-fertilizers. They are special liquid formulations containing not only the desired microorganisms and their nutrients but also special cell protectants or chemicals that promote formation of resting spores or cysts for longer shelf life and tolerance to adverse conditions (1). Peat and lignite, good sources of carrier materials are available only in very limited places like Nilgiris and Neyveli, thus resulting in high cost of transportation to bio-fertilizers manufacturing units. The liquid bio-fertilizer of good quality holds great promise over the carrier material transport, pulverization and sterilization, convenience in handling, storage and transportation and better performance (2).

Materials and methods

An experiment was conducted at Regional Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during rabi season of two consecutive years 2004-05 and 2005-06.

Geographically, Sardarkrushinagar is situated at 24^0-19' North latitude and 72^0-19' East longitude with an elevation of 154.52 metres above the mean sea level. It is located in the North Gujarat Agro-climatic zone and characterized by sub-tropical monsoon type semi-arid climate with extreme cold winter, hot and dry windy summer. The soil was sandy loam, very low in organic carbon (0.15%) and available N (168.0 kg/ha), medium in available P_2O_5 (32.4 kg/ha) and K_2O (234.0 kg/ha). The experiment comprising three main plot treatments of moisture stress viz., no moisture stress (irrigation schedules on early vegetative, active vegetative, flowering, grain formation and grain filling stages) stress at active vegetative stage and stress at active vegetative and grain filling stage, and seven treatments of nitrogen management with bio-fertilizers viz., No nitrogen(N_0), N_{40}, N_{40}+Azotobacter liquid, N_{40}+ Azotobacter powder(N_4), 60 kg N/ha(N_5), N_{60}+Azotobacter liquid and N_{60}+Azotobacter powder in sub plots was laid out in split plot design with four replications. Phosphorus @ 40 kg P_2O_5/ha from single super phosphate (SSP) was applied as a basal dose in ploughed furrows before sowing. Nitrogen from urea, was applied at two levels viz., 40 and 60 kg/ha, each in two equal splits as per treatments. Half of N was applied as basal at the time of sowing in furrows and the remaining half as top dressing at first irrigation in (early vegetative stage) the respective plots. Liquid agar slant and lignite carrier based culture of Azotobacter(*Azotobacter chroococcum*) strain ABA-1 were used. The seeds of amaranth Cv. GA-2 were first inoculated with Azotobacter (ABA-1) culture one hour before sowing. Carrier based culture(powder) was suspended in 10% jaggery solution and the seeds were thoroughly mixed in it to have uniform coating. The seeds and quantity of culture used was adjusted accordingly. Usually 200 gm of lignite based culture is sufficient for one kilogram seed. Liquid agar slant Azotobacter culture @ 20 ml per one kg seed was sprinkled on seeds spread in thin layer and mixed. As a sticker, jaggery solution was used. The seeds were thoroughly mixed and then allowed to dry in the shade for an hour before sowing. These treated seeds were utilized for sowing as per treatments. The seeds were sown keeping row to row distance of 45 cm using a seed rate 1.0 kg/ha. One common irrigation of 50 mm depth was applied at the time of sowing. Same depth was followed in subsequent irrigations in respective treatments.

Results and discussion

Yield

The outcome of the investigation revealed that grain and stover yield were decreased with increase in moisture stress (Table 1). No moisture stress showed its significant superiority. Significantly the lowest grain yield was recorded with treatment stress at active vegetative stage and grain filling stage. The magnitude of increase in grain yield by no moisture stress was to the tune of 15.40, 17.99 and 16.58 per cent over stress at active vegetative stage as well as 21.79, 22.35 and 22.07 per cent over stress at active vegetative as well as grain filling stage. This is attributed to longest main inflorescence, more number of lateral spikelets and 1000 seeds weight. The reduction in grain yield under stress at active vegetative stage over no moisture stress was worked out to 13.35, 15.25 and 14.22 % whereas the decrease under stress at active vegetative as well as grain filling stage over stress at only active vegetative stage was noted to 5.25, 3.56 and 4.50 per cent. This indicated that the active vegetative stage in grain amaranth crop is most critical for irrigation as compared to grain filling stage. Like grain yield, no moisture stress produced 21.45 and 28.28 per cent higher stover yield over stress at active vegetative and active vegetative as well as at grain filling stage, respectively. This is

Table 1. Yield attributes and yield of grain amaranth as influenced by moisture stress and nitrogen management with bio- fertilizers

Treatment	Stem thickness (cm)	Length of main inflorescence (cm)	Number of lateral spikelets per plant	1000 seeds weight (g)	Grain yield (kg/ha)			Stover yield (kg/ha)		
					2004-05	2005-06	Pooled	2004-05	2005-06	Pooled
Moisture stress										
No moisture stress	1.06	73.11	55.00	0.68	1386	1259	1322	4539	4214	4377
Stress at AVS	1.00	66.39	53.13	0.66	1201	1067	1134	3647	3562	3604
Stress at AVS & GFIS	0.96	63.32	50.39	0.63	1138	1029	1083	3431	3392	3412
SEm±	0.01	0.87	0.70	0.01	26.5	22.6	17.4	83.1	64.5	52.6
CD(P=0.05)	0.04	2.68	2.14	0.03	91.6	78.2	53.6	287.6	223.1	162.1
N management										
No N	0.64	44.24	39.72	0.63	526	428	477	1934	1670	1802
40 kgN/ha	1.02	65.00	52.88	0.65	1112	1002	1057	3670	3461	3665
40 kgN/ha+Azotobacter liquid culture	1.04	67.01	53.67	0.65	1240	1117	1178	3934	3880	3907
40 kgN/ha+Azotobacter powder culture	1.03	66.00	53.62	0.66	1204	1084	1144	3844	3696	3770
60 kgN/ha	1.10	73.98	56.03	0.66	1446	1298	1372	4411	4214	4313
60 kgN/ha+Azotobacter liquid culture	1.11	79.18	57.33	0.68	1610	1473	1542	4712	4557	4634
60 kgN/ha+Azotobacter powder culture	1.11	77.83	56.63	0.68	1553	1425	1489	4603	4581	4592
SEm±	0.02	1.05	0.90	0.01	31.1	29.0	21.3	75.1	84.3	56.5
CD(P=0.05)	0.05	2.95	2.51	0.03	88.5	82.7	59.7	213.9	240.4	158.5

AVS= Active vegetative stage, GFIS= Grain filling stage

attributed to behind this maximum plant height and stem thickness recorded with no moisture stress. These results corroborate the findings of Mishra *et al.* (3). Moreover water stress at active vegetative stage adversely affected the development of floral primordia, and the effect extended to grain formation and ultimately poor grain yield. (Gowda *et al.* (4) and Nehra (5).

The nitrogen management with bio-fertilizers treatments showed conspicuous effect on grain and stover yield of amaranth during both the years as well as in pooled data (Table 1). Treatment N_{60}+Azotobacter liquid achieved maximum grain yield which accounted 3.56, 12.39 and 45.88 per cent higher over N_{60}+Azotobacter powder, N_{60}, and N_{40}, in pooled, respectively. In case of stover yield, N_{60}+ Azotobacter liquid and N60+Azotobacter powder produced maximum stover yield during first and second year, respectively. While in pooled results, N_{60}+Azotobacter liquid come out with maximum stover yield of 4634 kg/ha. Increase in nitrogen level with or without Azotobacter, brought remarkable increase in stover yield. Azotobacter treatments either liquid or powder form with levels of nitrogen did not differ from each other and help to increase grain as well as stover yield over respective levels of nitrogen except powder form with N40 during both the years as well as in pooled data for stover. The combined effect of growth and yield attributes has helped to improve grain yield. Higher grain yield was associated with higher length of main inflorescence, more number of lateral spikelets, Similarly higher stover yield was associated with higher plant height and maximum stem thickness. These results are broadly in conformity with those reported by Arya and Singh (6), Deokar and Sawant (7) and Rathore *et al.*(8).

Nutrients content and uptake

Calcium and nitrogen content in grain (Table 2) were significantly influenced by moisture stress. Iron and phosphorus content in grains not influenced due to moisture stress Adequate moisture supply brought distinct improvement in calcium and N content. No moisture stress contributed maximum nitrogen content in grains accounting 3.32 and 4.45 per cent higher over stress at active vegetative stage and stress at active vegetative as well as grain filling stage in two years pooled mean. This might be due to transformation of nutrients in soluble forms which are readily available to plants with continuous and sufficient moisture availability. Besides it might have created favourable micro climate condition for microbial activity and thereby mineralization. Moisture stress at two growth stages led to minimum content of calcium and nitrogen in grain. However, moisture stress did not change iron content in grain(Table 2). Improvement of quality parameters under no stress treatment might be due to adequate availability of moisture throughout the life period of crop and thereby continuous availability of required nutrients to plants due to solubility and ionization of nutrients under favourable conditions.

The uptake of nitrogen by the crop was influenced due to moisture stress(Table 3). Maximum uptake of nitrogen was noticed with no moisture stress followed by moisture stress at active vegetative stage. Missing two irrigations(stress at active vegetative and grain filling stage) led to minimum uptake of nitrogen. The reduction in total uptake of nitrogen by crop due to moisture stress at active vegetative stage and at active vegetative and grain filling stage was to the tune of 17.96 and 22.71 per cent over no stress, respectively. This indicated that supply of sufficient moisture to the crop led better utilization of nitrogen. Similar trend was also observed in case of phosphorus uptake by crop (Table 3). Treatment no moisture stress treatments registered 19.34 per cent higher phosphorus uptake over stress at active vegetative stage, whereas, 25.11 per cent higher over stress at active vegetative and grain filling stage by the crop. This might be due to increase in mass flow transport of nutrients with sufficient soil moisture availability. These findings are in accordance with those reported by Patel (9).

Maximum nitrogen, calcium and iron content in grain was recorded under N_{60} +Azotobacter liquid(Table 2). The increasing trend in nutrients content in grain was observed with increase in levels of nitrogen. Neither liquid nor power forms of Azotobacter with respective levels of nitrogen vary in terms of nutrients content in grains. Phosphorus content in grain was markedly increased and found maximum with N_{60} +Azotobacter liquid) during first year.

Regarding N uptake by crop, N_{60} + Azotobacter liquid showed its superiority followed by N_{60} + Azotobacter powder (Table 3). The increase in uptake of N is attributed to the favourable effect of Azotobacter inoculation on growth and yield attributes which resulted in higher grain and stover yield and promoting N content in grain which resulted in higher N uptake. Azotobacter treatment either liquid or powder form with respective levels of nitrogen remained at par with each other however increase in levels of nitrogen brought increment in nitrogen uptake. This might be due to fixation of molecular nitrogen by

Table 2. Content of nutrients in grain amaranth as influenced by moisture stress and nitrogen management with bio-fertilizers.

Treatments	Calcium content in grain (%)			Iron content in grain (ppm)			Nitrogen content (%)			Phosphorus content (%)		
	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled
Moisture stress												
No moisture stress	0.45	0.44	0.45	154.03	151.48	152.76	2.29	2.30	2.29	0.46	0.45	0.45
Stress at AVS	0.44	0.43	0.44	150.64	148.88	149.76	2.23	2.21	2.22	0.46	0.45	0.46
Stress at AVS & GFIS	0.44	0.41	0.43	148.61	147.17	147.89	2.21	2.18	2.19	0.47	0.45	0.46
SEm±	0.004	0.005	0.003	1.58	2.05	1.29	0.03	0.03	0.02	0.01	0.01	0.01
CD(P=0.05)	NS	0.017	0.010	NS	NS	NS	NS	0.10	0.07	NS	NS	NS
N management												
No N	0.41	0.38	0.40	146.24	144.26	145.25	2.03	1.99	2.01	0.45	0.44	0.45
40 kgN/ha	0.44	0.41	0.42	149.04	146.80	147.92	2.18	2.15	2.16	0.46	0.45	0.45
40 kgN/ha+ Azotobacter liquid	0.45	0.42	0.43	152.10	147.57	149.84	2.21	2.22	2.21	0.46	0.45	0.46
40 kgN/ha+ Azotobacter powder	0.45	0.42	0.43	151.24	146.80	149.02	2.19	2.20	2.19	0.46	0.45	0.45
60 kgN/ha	0.46	0.44	0.45	152.17	151.89	152.03	2.34	2.31	2.32	0.47	0.45	0.46
60 kgN/ha+ Azotobacter liquid	0.47	0.46	0.46	153.94	154.11	154.02	2.40	2.38	2.39	0.48	0.46	0.47
60 kgN/ha+ Azotobacter powder	0.46	0.46	0.46	152.91	152.82	152.86	2.36	2.35	2.36	0.47	0.46	0.46
SEm±	0.005	0.006	0.004	1.55	1.79	1.18	0.04	0.03	0.02	0.005	0.007	0.004
CD(P=0.05)	0.01	0.02	0.01	4.41	5.11	3.33	0.10	0.08	0.06	0.01	NS	NS

AVS= Active vegetative stage, GFIS= Grain filling stage

Table 3. Nitrogen and phosphorus uptake by grain amaranth as influenced by moisture stress and nitrogen management with bio-fertilizers.

Treatments	Nitrogen uptake by crop (kg/ha)			Phosphorus uptake by crop (kg/ha)		
	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled
Moisture stress						
No moisture stress	71.26	65.94	68.60	11.89	11.44	11.66
Stress at AVS	58.39	54.16	56.28	9.99	9.54	9.77
Stress at AVS & GFIS	54.95	51.09	53.02	9.49	9.15	9.32
SEm±	1.17	0.88	0.73	0.14	0.17	0.11
CD(P=0.05)	4.06	3.04	2.26	0.49	0.58	0.34
N management						
No N	25.66	21.04	23.35	4.56	4.02	4.29
40 kgN/ha	54.60	49.06	51.83	9.48	9.01	9.24
40 kgN/ha+ Azotobacter liquid	59.82	57.25	58.54	10.29	10.24	10.27
40 kgN/ha+ Azotobacter powder	58.20	54.34	56.27	10.08	9.79	9.93
60 kgN/ha	73.26	66.89	70.07	12.23	11.57	11.90
60 kgN/ha+ Azotobacter liquid	81.00	76.24	78.62	13.56	12.93	13.24
60 kgN/ha+ Azotobacter powder	78.21	74.62	76.41	13.02	12.73	12.88
SEm±	1.21	1.23	0.87	0.21	0.24	0.16
CD(P=0.05)	3.46	3.51	2.43	0.60	0.69	0.45

AVS= Active vegetative stage, GFIS= Grain filling stage

Azotobacter. However, soils of experimental plot responded well to Azotobacter treatment due to poor nitrogen status. Nitrogen management treatments had spectacular impact on phosphorus uptake by the crop(Table 3). Treatment N_{60} +Azotobacter liquid ranked at top followed by N_{60} +Azotobacter powder) in case of phosphorus uptake. Azotobacter either liquid or powder form with respective levels of nitrogen did not contribute for increase in uptake of phosphorus except with higher level of nitrogen. This might have promoted growth of roots as well as functional activities and duration leading to higher nutrient extraction from the soil and translocation of them to aerial parts of the plant. Moreover, favourable effect of Azotobacter on yield attributes of amaranth and resultant effect on grain and stover yield (Table 1) under these treatments and ultimately higher phosphorus uptake. These results are in agreement with those reported by Panchal (10) in case of uptake of nutrients. Similar positive response of Azotobacter in content and uptake of nitrogen and phosphorus has also been observed by Singh and Totawat (11) in maize crop.

Conclusion

Irrigating the crop at all physiological growth stages i.e. no moisture stress and supplying 60 kg N / ha alongwith seeds inoculating by Azotobacter liquid culture gave maximum yield of grain amaranth. Maximum content and uptake of nutrients also registered with 60 kg N / ha alongwith seeds inoculating by Azotobacter liquid culture under assured irrigations.

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