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Effect of nitrogen management on yield, water use and nutrient uptake of grain amaranth (*Amaranthus hypochodriacus*) under moisture stress

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ABSTRACT

An experiment was conducted at Sardarkrushinagar during 2004-05 and 2005-06 on sandy loam soil to find out response of grain amaranth to moisture stress (*viz.,* no moisture stress, stress at active vegetative stage; and stress at active vegetative as well as grain filling stage) and N management (No N, 40 kg N /ha, 40 kg N /ha with *Azotobacter* liquid and powder 60 kg N /ha, 60 kg N /ha with *Azotobacter* liquid and powder). The study revealed that without moisture stress grain amaranth gave 16.58 and 22.07 % higher grain yield over moisture stress imposed at active vegetative stage and at 2 growth stages, respectively in pooled data. However, the lowest water use (5.30 kg/ha-mm) and expense efficiency (4.41 kg/ha-mm) was obtained with maximum water consumption (246.2 mm) under no moisture stress. Among the N management treatments, 60 kg N/ ha integrating seed inoculation with *Azotobacter* liquid culture brought remarkable improvement in stem thickness, length of main inflorescence, number of lateral spikelets and 1,000 seed weight which resulted in increase in grain and stover yields. Application of 60 kg N /ha +*Azotobacter* liquid showed its superiority in terms of consumption of water (218.6 mm), water use (7.19 kg/ha-mm) and expense efficiency (6.17 kg/ha-mm). Integration of 60 kg N /ha + *Azotobacter* liquid culture realized 9.42 and 11.26 % higher N and P uptake over 60 kg N /ha alone. Significant contribution of seed inoculation was noted on yield with interactive effect of moisture stress and with higher level of N. It can be concluded that application of 60 kg N/ha alongwith seed inoculation (*Azotobacter* liquid culture) under assured irrigation recorded the maximum values of yield, water use, nutrient uptake, and net returns.

Key words: *Amaranthus,* Crop yield, Economics, Management, Moisture content, Water use

Grain amaranth (*Amaranthus hypochondriacus* L.) is a potential upcoming subsidiary food crop of the future. It is said to be highly nutritious with higher protein and lycine content than almost any other cereals. Besides a better source of enriched infant food, the unique features of amaranth *viz.,* low water and input requirement, tolerance to stress with lesser growing period have created interest among the farmers for its cultivation in arid and semi-arid regions of Gujarat. Application of irrigation water at critical growth stages without reduction in yield is one of the approaches for enhancing water use efficiency for amaranth (Gowda *et al.,* 1999 and Ayodele, 2000). N forms a basic input for the growth of the plant. The increasing cost of fertilizers and its scarce availability lead to incredible rise in cost of production and thereby decrease in profit. Integration of cost effective and eco-friendly bio-fertilizers with chemical fertilizers is the way out for saving N fertilizers. Recently, interest has aroused to produce liquid bio-fertilizers, which 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 (Bhattacharya and Kumar, 2002). 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 (Hegde, 2002).

MATERIALS AND METHODS

A field experiment was conducted during *rabi* of 2 consecutive years 2004-05 and 2005-06 at Regional Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. 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 summers. The soil was sandy loam, very low in organic carbon (0.15%) and available N

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(168.0 kg/ha), medium in available P_2O_5 (32.4 kg/ha) and K_2O (234.0 kg/ha). Treatments comprising combinations of moisture stress *viz.*, no moisture stress (irrigation schedules at 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 7 treatments of N management with biofertilizers *viz.*, No N, 40 kg N/ha, 40 kg N/ha + *Azotobacter* liquid, 40 kg N/ha + *Azotobacter* powder, 60 kg N/ha, 60 kg N/ha +*Azotobacter* liquid and 60 kg N/ha + *Azotobacter* powder were replicated 4-fold in split plot design.

The crop was sown on 11 November 2004 and 7 November 2005. Moisture stress at active vegetative stage (24 December 2004 and 16 December 2005) and grain filling stage (7 February 2005 and 2 February 2006) during both the seasons. Phosphorus @ 40 kg P_2O_5/ha was applied from single super phosphate as basal in ploughed furrows before sowing. N from urea, was applied in 2 equal splits as per treatments. Half of N was applied as basal at the sowing in furrows and the remaining half as top dressing at first irrigation (early vegetative stage) in the respective plots. Liquid agar slant and lignite carrier based culture of Azotobacter (*Azotobacter chroococcum*) strain ABA 1 were used. The seeds of amaranth '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 g of lignite-based culture is sufficient for 1 kg seed. Liquid agar slant *Azotobacter* culture @ 20 ml/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 1 hr before sowing. These treated seeds were utilized for sowing as per treatments. The seeds were drilled keeping row-to-row distance of 45 cm using seed rate 1.0 kg/ha. One common irrigation of 50 mm depth was applied at the sowing and subsequent irrigations were applied as per schedule maintaining same depth measuring by Parshall flume, having a throat width 15 cm, installed at head of the experimental plot. The number of irrigations schedules were 5, 4 and 3 at no moisture stress, moisture stress one growth stage and two growth stages respectively. Soil moisture studies were carried out by drawing soil samples before sowing, just before each irrigation and 24 hr after each irrigation as well as at harvest. Sampling was performed with the help of screw auger from 0-30, 30-60, 60-90 and 90-120 cm soil depth. Moisture use by crop such as consumptive use(CU), water use efficiency (WUE) and water expense efficiency (WEE) were computed following the method suggested by Dastane(1972). The gross realization was worked out on the basis of mean grain and stover yield/ha of each treatment and market price of that year. The net realization was calculated by deducting the total cost of cultivation from the gross realization for each treatment. The benefit cost ratio (BCR) was calculated on the basis of the formula given below:

$$\text{BCR} = \frac{\text{Gross realization (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

RESULTS AND DISCUSSION

Yield and yield attributes

The outcome of the investigation revealed that grain and stover yield decreased with increase in moisture stress (Table 1). No moisture stress exhibited its significant superiority. Significantly the lowest grain yield was recorded when stress imposed at active vegetative + grain filling stage. The magnitude of increase in grain yield with no moisture stress was to the tune of 15.40 and 17.99% over stress at active vegetative stage (AVS) as well as 21.79 and 22.35% over stress at AVS and grain filling stage (GFIS) respectively during 2004-05 and 2005-06. The yield increment is attributed to improvement in length of main inflorescence, number of lateral spikelets and 1,000 seeds weight (Table 1). The reduction in grain yield under stress at AVS over no moisture stress is worked out to 13.35 and 15.25% during first and second year respectively. However, the differences in yield were observed marginal when stress imposed either at 1 or 2 growth stages. This indicated that the AVS is most critical for irrigation as compared to GFIS in grain amaranth crop. Like grain yield, no moisture stress produced 21.45 and 28.28% higher stover yield over stress at AVS and AVS + GIFS, respectively. Higher stover yield is ascribed to increment in plant height and stem thickness recorded with no moisture stress. These results corroborate with the findings of Mishra *et al.* (1997). Moreover moisture stress at AVS adversely affected the development of floral primordia, and the effect extended to grain formation and ultimately poor grain yield (Gowda *et al.,* 1999 and Nehra, 2000).

Integration of biofertilizers with N exerted affirmative effect on grain and stover yield over only N application during both the years and in pooled data (Table 1). Treatment N_{60}+liquid culture produced maximum grain yield which accounted 3.56, 12.39 and 45.88 % higher over N_{60}+powder, N_{60} and N_{40}, respectively. The same treatment (N_{60}+liquid culture) expressed its superiority producing stover yield of 4.63 t/ha. In general, both the forms (powder and liquid) found equally effective with respective level of N. Higher grain yield is associated with higher length of main inflorescence, more number of lateral spikelets and 1,000 seeds weight (Table 1). Similarly higher stover yield is ascribed to higher plant height and maximum stem thickness (Table 1). Similar findings have been reported by Arya and Singh (2001), Deokar and Sawant (2002) and Rathore *et al.* (2004).

Water use

The consumptive use of water (CU) decreased as moisture stress increased. Maximum CU of water was recorded under no moisture stress that was 22.98 and 53.20% higher than that of stress at AVS (active vegetative stage) and stress at AVS + GFIS (grain filling stage) on mean basis, respectively. Higher CU with more number of irrigations is attributed to luxurious growth under adequate moisture supply, which inturn increased the evapotranspiration losses. On the other hand, limited water supply under stress at AVS + GFIS reduced vegetative growth of the crop thereby less consumption. Water use efficiency (WUE) and water expense efficiency (WEE) were elevated as moisture stress raised. It followed the law of diminishing return being highest with three irrigations (early vegetative, flowering and grain formation) and lowest

Table 1. Yield attributes and yield of grain amaranth as influenced by moisture stress and N management with biofertilizers

Treatments	Plant height (cm)	Stem thickness (cm)	Length of main inflores-cence (cm)	Number of lateral spikelets/ plant	1000 seeds weight (g)	Grain yield (t/ha)		Stover yield (t/ha)	
						2004-05	2005-06	2004-05	2005-06
Moisture stress									
No at stress	147.4	1.06	73.11	55.00	0.68	1.39	1.26	4.54	4.21
Stress at AVS	138.9	1.00	66.39	53.13	0.66	1.20	1.07	3.65	3.56
Stress at AVS and GFIS	135.0	0.96	63.32	50.39	0.63	1.14	1.03	3.43	3.39
SEm±	1.6	0.01	0.87	0.70	0.01	0.03	0.02	0.08	0.06
CD(P=0.05)	4.7	0.04	2.68	2.14	0.03	0.09	0.08	0.29	0.22
N management (kg/ha)									
No N	99.7	0.64	44.24	39.72	0.63	0.53	0.43	1.93	1.67
40	140.8	1.02	65.00	52.88	0.65	1.11	1.00	3.67	3.46
40 *Azotobacter* liquid culture	144.1	1.04	67.01	53.67	0.65	1.24	1.12	3.93	3.88
40 *Azotobacter* powder culture	142.4	1.03	66.00	53.62	0.66	1.20	1.08	3.84	3.70
60	149.1	1.10	73.98	56.03	0.66	1.45	1.30	4.41	4.21
60 *Azotobacter* liquid culture	154.1	1.11	79.18	57.33	0.68	1.61	1.47	4.71	4.56
60 *Azotobacter* powder culture	153.0	1.11	77.83	56.63	0.68	1.55	1.43	4.60	4.58
SEm±	1.8	0.02	1.05	0.90	0.01	0.03	0.03	0.08	0.08
CD(P=0.05)	4.9	0.05	2.95	2.51	0.03	0.09	0.08	0.21	0.24

AVS, Active vegetative stage; GFIS, Grain filling stage.

Table 2. Consumptive use of water, water use and water expense efficiency as influenced by moisture stress and N management

Treatments	Total quantity of water applied (mm)	Consumptive use of water (mm)		Water use efficiency (kg/ ha-mm)		Water expense efficiency (kg/ ha-mm)	
		2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Moisture stress							
No moisture stress	300	237.9	254.5	5.75	4.85	4.62	4.20
Stress at AVS	250	187.0	213.3	6.37	4.93	4.80	4.27
Stress at AVS & GFIS	200	155.1	166.3	7.25	6.11	5.69	5.14
N management (kg/ha)							
No N	250	176.5	186.2	3.03	2.35	2.10	1.71
40	250	183.2	196.3	6.20	5.21	4.45	4.01
40 *Azotobacter* liquid culture	250	189.9	212.5	6.71	5.36	4.96	4.47
40 *Azotobacter* powder culture	250	185.4	200.9	6.65	5.49	4.81	4.33
60	250	204.0	225.3	7.16	5.84	5.78	5.19
60 *Azotobacter* liquid culture	250	204.6	232.7	7.97	6.42	6.44	5.89
60 *Azotobacter* powder culture	250	209.8	225.8	7.47	6.42	6.21	5.70

with adequate irrigations. Similar findings have been reported by Patel *et al.* (2005).

Maximum CU of water, WUE and WEE were registered with N_{60} + liquid culture (Table 2). This might be due to luxurious vegetative growth of crop when N requirements are fulfilled. Appreciable increase in WUE and WEE were observed with *Azotobacter* treatments either liquid or powder form combined with N over N alone. These findings followed the pattern with Arya and Singh (2001).

Interaction between moisture stress and N management was found significant (Table 3). No moisture stress with N_{60}+*Azotobacter* liquid culture remaining at par with no moisture stress with N_{60}+ powder culture produced maximum grain yield, which accounted 12.0 to 13.4 % increase over N_{60} under varying moisture stress. Similar response of liquid form was noted with N_{40} and N_{60} over N alone at all the stress levels. Rapid growth of *Azotobacter* under adequate N supply with irrigations during initial crop growth might have helped in better performance of *Azotobacter* culture treatments.

Nutrient uptake

Maximum uptake of N and P by the crop was noticed with no moisture stress and moisture stress at active vegetative + grain filling stage led to minimum uptake (Table 4). This indicated that supply of sufficient moisture to the crop led better utilization of N and P. This might be due to increase in mass flow nutrients with sufficient soil moisture availability. (Table 4). Among all the N treatments, N_{60} + liquid culture ranked at top followed by N_{60} + powder culture. The increase in uptake of N is attributed to the favourable effect of *Azotobacter* inoculation on growth and yield attributes (Table 1) which resulted in higher

Table 3. Interaction effect of moisture stress and N management on amaranth grain yield (t/ha) (Pooled data)

Moisture stress	N management						
	N0	N40	N40 + *Azotobacter* liquid culture	N40 + *Azotobacter* powder culture	N60	N60 + *Azotobacter* liquid culture	N60 + *Azotobacter* powder culture
No moisture stress	0.52	1.13	1.29	1.26	1.57	1.78	1.71
Stress at active vegetative stage	0.47	1.03	1.16	1.13	1.30	1.45	1.41
Stress at AVS and GFIS	0.45	1.01	1.08	1.05	1.25	1.40	1.35
SEm±				0.04			
CD (P=0.05)				0.10			

AVS, Active vegetative stage; GFIS, Grain filling stage

Table 4. Nutrients uptake and economics (Rs/ha) as influenced by moisture stress and N management with biofertilizers

Treatments	Nutrients uptake by crop (kg/ha)				Economics			
	N		P		Gross realization	Cost of Cultivation	Net realization	BCR
	2004-05	2005-06	2004-05	2005-06				
Moisture stress								
No moisture stress	71.26	65.94	11.89	11.44	25,775	8,119	17,655	3.17
Stress at AVS	58.39	54.16	9.99	9.54	22,087	7,805	14,282	2.83
Stress at AVS & GFIS	54.95	51.09	9.49	9.15	21,089	7,491	13,598	2.82
SEm±	1.17	0.88	0.14	0.17				
CD (P=0.05)	4.06	3.04	0.49	0.58				
N management								
No N	25.66	21.04	4.56	4.02	9,333	7,214	2,119	1.29
40 kgN/ha	54.60	49.06	9.48	9.01	20,633	7,784	12,849	2.65
40 kgN/ha+*Azotobacter* liquid culture	59.82	57.25	10.29	10.24	22,968	7,788	15,180	2.95
40 kgN/ha+*Azotobacter* powder culture	58.20	54.34	10.08	9.79	22,302	7,791	14,510	2.86
60 kgN/ha	73.26	66.89	12.23	11.57	26,715	8,015	18,699	3.33
60 kgN/ha+*Azotobacter* liquid culture	81.00	76.24	13.56	12.93	29,993	8,020	21,973	3.74
60 kgN/ha+*Azotobacter* powder culture	78.21	74.62	13.02	12.73	28,980	8,023	20,957	3.61
SEm±	1.21	1.23	0.21	0.24				
CD (P=0.05)	3.46	3.51	0.60	0.69				

AVS, Active vegetative stage; GFIS, Grain filling stage yield and higher N uptake.

Economics

Among the moisture stress treatments; realized the highest net return and also the BCR (Table 4). Similar findings have been reported by Patel *et al*. (2005). The highest net realization and BCR were accrued with treatment N_{60}+*Azotobacter* liquid culture.

It was concluded that grain amaranth under assured irrigation application of 60 kg N/ha alongwith seed inoculation by *Azotobacter* liquid culture, gave maximum yield, BCR and N as well as P uptake.

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