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Productivity and profitability enhancement in grain amaranth (*Amaranthus hypochondriacus* L.) through use of sulphur fertilization in hilly region of Uttarakhand

Rahul Rana, Arunima Paliwal, Ajay Kumar, Shikha and Gargi Goswami

Abstract
A field experiment was conducted during *Kharif* season of 2018 and 2019 at Research and Extension Center, Gaja, College of Forestry, VCSG Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal, Uttarakhand, India to investigate the response of sulphur fertilization on yield attributing, seed yield and economics of grain amaranth. Two varieties and four fertilizer doses were tested in split plot design with three replications. The data indicated that among the varieties, PRA-3 performed well as compared to Annapurna. However among fertilizer doses, RDF + Sulphur @ 20 kg/ha showed maximum growth, yield attributes, seed yield and economics of grain amaranth.

Keywords: Grain amaranth, nutricereal, protein rich, sulphur fertilization

Introduction

Grain amaranth (*Amaranthus hypochondriacus* L.) a nutricereal, is a multicultural genus of herb (Narwade and Pinto, 2018) [16], called as "Gentle giant or Super grain". It is one of the disremembered food crops of the world. It has potentiality as subsidiary food and plays a vital role in feeding the hunger world (Gunjal, 2011) [7]. In African countries, it is a vital nutritious food in regards to treat those suffering from HIV/AIDS (Alegbejo, 2013) [1]. Amaranths are valued as leafy vegetables and cereals. Amaranth species are receiving great attention in developing countries as a medium to fight protein malnutrition, due to the presence of high seed protein (about 16%) which is much higher than most of the common grains like rice and wheat (Singhal and Kulkarni, 1988; Oleszek *et al*, 1999) [22, 17]. They are protein rich pseudo-cum-nutri cereals and also called as poor man vegetable, that holds cultural significance in remote and tribal areas in many part of India particularly in the Himalayan region. Amaranth grain contains 6 to 10% oil, which is found mostly within the embryo (Betschart *et al*, 1981; Lorenz and Hawang, 1985; Garcia *et al*, 1987) [3, 15, 6]. In India, it is grown from tropical lowlands to 3500 m above mean sea level height in the Himalayas (Sauer, 1967) [20]. The crop is mainly cultivated both in hilly regions as well as in plains, in the states of Uttarakhand, Himachal Pradesh, Gujarat, Maharashtra and Karnataka. Tribes of India use the grains for treating measles and snakebites as well as for foot and mouth diseases in animals (Joshi and Rana, 1991) [11].

It play a vital role in the socio-economic condition of small and marginal farmers of hilly areas of Uttarakhand. The area of cultivation of grain amaranth is spreading about 6108 ha with production of 6104 MT having productivity of 9.99 q/ha in Uttarakhand (2016-17). In Uttarakhand, grain amaranth is mainly used in preparation of laddu, halwa and chapati mixed with wheat flour. The most important constraints to crop growth are those caused by poor variety selection and improper plant nutrients. Improved varieties with nutrient management practices could improve the productivity of grain amaranth. Among major plant nutrients, sulphur is recognized as the fourth important after nitrogen, phosphorus and potassium in all the crops, but its importance has not so far fully relished by farmers in amaranth. Unfortunately, degree and spread of sulphur deficiency in Indian soil are gradually increasing (Patel *et al*., 2018) [18]. Investigations have revealed that the yield and yield attributes of wheat significantly respond to the application of sulphur fertilizer (Inal *et al*., 2003; Khan *et al*., 2003; Girma *et al*., 2005) [8, 12, 5]. Several studies by Ja¨rvan and Adamson, 2005 [9]; Ja¨rvan *et al*., 2009 [10]; Salvagiotti *et al*., 2009 [19] have shown that sulphur fertilization may increase the efficiency of nitrogen use. Thus, balanced fertilization to crop with sulphur is essential. Hence there is need to find suitable variety of grain amaranth for hill region of Uttarakhand under sulphur fertilization for achieving economically potential yield.

Material and Method

The field experiment was conducted at Research and Extension Center, Gaja, College of Forestry, VCSG Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal, Uttarakhand, India. The center is situated at 30°26 N latitude and 78°41 E longitudes and altitude of 1750 meter above MSL. The experiment was conducted during *Kharif* season of 2018-19and 2019-2020to investigate the response of sulphur fertilization on yield attributing, seed yield and economics of grain amaranth. The climate of Gaja is sub humid and temperate with chilled winter. The soil was silty clay loam in texture with slightly acidic pH (5.6) characterized by 225.8 kg/ha available nitrogen, 9.1 kg/ha available phosphorous, 201.6 kg/ha available potassium, 6.0 ppm available sulphur with 0.83% organic carbon and low electrical conductivity (0.031 dSm/m).The experiment consist of 3-replicated eight treatment combinations with two varieties (Annapurna, PRA-3) and four fertilizer doses (RDF only *i.e.* NPK @ 60:40:20, RDF + Sulphur @ 20 kg/ha, RDF + Sulphur @ 40 kg/ha and control)laid out in split plot design. The crop was sown in lines 50 cm apart with plant-to-plant distance 10 cm on 25.05.2018 and 30.05.2019, respectively during both the years of study. Intercultural operations were done as and when necessary. The crop was fertilized with recommended dose of fertilizers (RDF) using urea, DAP and MOP. Sulphur was given through elemental sulphur at 20 kg and 40 kg sulphur per hectare (as per treatment). Half dose of nitrogen was applied as basal at the time of sowing and remaining was top dressed after 45 days of sowing. However, full dose of phosphorus, potassium and sulphur was applied at the time of sowing. The data of crop yield attributing traits and seed yield was taken using standard procedure. The data obtained during the course of investigation were statistically analyzed by using STPR-1 programme for the Split Plot Designdesigned and developed by Department of Mathematics and Statistics of College of Basic Science and Humanities (CBSH), GBPUA&T, Pantnagar and O.P. Sheoran Programmer, Computer Section, CCS HAU, Hisar, respectively.

Result and Discussion

The yield attributing characters like inflorescence length, number of finger per inflorescence and finger length were not affected significantly by the two varieties. However, they were significantly affected by different fertilizer doses except finger length during 2019. Also there interaction was found non-significant. However, maximum inflorescence length, number of finger per inflorescence and finger length was obtained in PRA-3 followed by Annapurna. The maximum biological yield, grain yield and straw yield were recorded with PRA-3, during both the years of study, which was significantly higher than Annapurna (Table 1). This was due to contribution of higher yield attributing characters of PRA-3 variety.

Among various fertilizer doses, higher inflorescence length, number of fingers per inflorescence, biological yield, seed yield and straw yield were recorded with recommended dose of fertilizers (RDF) along with 20 kg/ha sulphur in comparison to the control and recommended dose of fertilizers (RDF). The finger length and 10 ml seed weight were recorded maximum with recommended dose of fertilizers (RDF) along with 40 kg/ha sulphur during both the years of study. RDF + S @ 20 kg/ha and RDF + S @ 40 kg/ha was statistically at par with each other for yield and yield attributing characters like inflorescence length, number of finger per inflorescence, finger length and 10 ml seed weight (Table 1). This might be due to sulphur that attributed to increase the yield attributes of grain amaranth. The sulphur also acted synergistically with nitrogen and increased the uptake of other nutrients which helps in better growth of green gram (Das, 2017) [4]. A study from Assam, reported that the grain and straw yield of black gram increased significantly up to 20 kg S/ha which was 95.7% higher over control (Basumatary *et al.*, 2018) [2]. The higher application of sulphur was responsible for the increase in leaf area and chlorophyll content of leaves which might cause higher photosynthesis and metabolic activity in plants which were responsible for the overall development of plants and increases yield and yield attributes of mustard (Kumar, 2015) [14]. Sharma *et al.* (2015) [21] from PAU, Ludhiana found that sulphur and nitrogen alone or in different combinations significantly increases the seed yield of soybean. A positive reaction of nitrogen and sulphur fertilization on grain yield of wheat was displayed by Klikocka *et al.* (2016) [13]. Srinivasulu *et al*. (2016) [23] from Junagadh, found that the application of 40 kg S/ha recorded higher grain yield, protein content and protein yield, net return and benefit cost ratio of chick pea after remaining at par with 20 kg S/ha. Harvest index was not influenced significantly by varieties and sulphur doses. However, PRA-3 reported high harvest index (17.4-17.9%) than Annapurna during both the years of study. While recommended dose of fertilizers alone registered the maximum harvest index (17.9-18.0%) followed by recommended dose of fertilizers along with 40 kg/ha sulphur during both the years of study (Table 1).

The PRA-3 variety showed 21.05 and 15.31% increase in pooled grain yield and straw yield, respectively over Annapurna. However, RDF with 20 kg/ha sulphur showed increase of 74.42 and 58.92% in pooled grain yield and straw yield, respectively over control and increase of 26.05 and 29.17% over recommended dose of fertilizers, respectively (Table 2). The PRA-3 variety of grain amaranth gave high net profit than the Annapurna as PRA-3 recorded higher grain yield which resulted to higher gross income while the cost of cultivation was same in case of both the varieties. Similarly, higher benefit cost ratio (4.6:1) was also recorded higher in case of PRA-3 than the Annapurna. The application of recommended dose of fertilizers along with 20 kg/ha sulphur recorded highest net profit followed by recommended dose of fertilizers along with 40 kg/ha sulphur because the cost of cultivation was lesser in case of RDF + S @ 20 kg/ha than RDF + S @ 40 kg/ha. Similarly, highest benefit cost ratio was recorded in RDF + S @ 20 kg/ha (4.9) and followed by RDF + S @ 40 kg/ha (4.4) (Table 2).

Based on the study, it may be concluded that PRA-3 cultivar is most economical high yielding cultivar of grain amaranth with the application of 20 kg sulphur/ha along with RDF (60:40:20) and may be recommended for rainfed conditions of Garhwal hilly region of Uttarakhand.

Table 1: Effect of varieties of amaranth and various fertilizer doses on yield attributing characters and yield

Treatments	Inflorescence length (cm)		No. of fingers/ inflorescence		Finger length (cm)		10 ml seed weight (g)		Biological yield (q/ha)		Seed yield (q/ha)		Straw yield (q/ha)		Harvest Index (%)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Variety																
Annapurna	56.8	54.2	26.5	25.8	19.5	18.8	10.6	9.9	69.4	64.4	12.0	10.8	57.4	53.6	17.4	16.8
PRA-3	59.5	57.9	29.4	27.9	20.3	19.3	11.3	10.4	80.0	75.5	14.4	13.3	65.6	62.3	17.9	17.4
S.Em±	1.5	1.8	0.8	0.5	0.6	0.5	0.1		1.2	0.7	0.3	0.4	1.3	0.3	0.5	
CD (P = 0.05)	NS						0.1	NS	7.2	4.0	1.6	NS	7.4	1.8	NS	
Fertilizer doses																
Control	53.4	47.6	23.7	22.6	17.7	16.8	10.2	9.2	54.1	51.5	9.3	7.9	44.8	43.6	17.3	15.3
RDF+ Sulphur @ 20 kg/ha	61.9	61.0	31.1	31.0	20.5	19.8	11.2	10.4	87.2	83.5	15.5	14.5	71.7	69.0	17.7	17.3
RDF+ Sulphur @ 40 kg/ha	59.9	59.6	30.1	28.7	22.5	21.4	11.4	11.2	86.5	83.2	15.3	14.7	71.2	68.5	17.7	17.7
RDF (60:40:20)	57.3	55.9	26.7	25.3	19.0	18.1	10.9	10.0	70.9	61.7	12.7	11.1	58.2	50.7	17.9	18.0
S.Em±	1.7	2.1	0.8	1.3	0.7	1.3	0.2	0.4	2.9		0.4	0.5	2.7	2.6	0.7	
CD (P = 0.05)	5.3	6.7	2.5	4.3	2.0	NS	0.5	1.3	8.8	9.3	1.3	1.6	8.4	8.6	NS	
Interaction	NS															

Table 2: Pooled yield and economics in amaranth to sulphur fertilization

Treatments	Seed yield (q/ha)	Straw yield (q/ha)	Cost of Cultivation (₹/ha)	Gross income (₹/ha)	Net profit (₹/ha)	B:C ratio (₹/ha)
Variety						
Annapurna	11.4	55.5	14490	68038	53548	3.7
PRA-3	13.8	64.0	14490	81848	67358	4.6
Fertilizer doses						
Control	8.6	44.3	11832	51720	39888	3.4
RDF+ Sulphur @ 20 kg/ha	15.0	70.4	15276	88945	73669	4.9
RDF+ Sulphur @ 40 kg/ha	15.0	69.9	16436	88965	72529	4.4
RDF (60:40:20)	11.9	54.5	14416	70140	55724	3.9

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