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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(9): 1146-1149

www.thepharmajournal.com
Received: 03-07-2021
Accepted: 13-08-2021

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The effect of irrigation and nitrogen levels on growth, yield and economics of grain amaranth (*Amaranthus hypochondriacus* L.)

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Abstract

A field experiment was conducted at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari to study the effect of irrigation and nitrogen levels on growth and yield of grain amaranth (*Amaranthus hypochondriacus* L.) during the *rabi* 2017-18. The treatment consisted combinations of four levels of irrigation *viz.*, 30 DAS (I_1), 30 DAS + 60 DAS (I_2), 30 DAS + 60 DAS + 75 DAS (I_3) and 0.8 IW: CPE (I_4) and three levels of nitrogen *i.e.*, 50% RDN (N_1), 75% RDN (N_2) and 100% RDN (N_3). The results revealed significantly higher growth and yield parameters with irrigation at 30 DAS + 60 DAS + 75 DAS (I_3). Significantly higher grain and stover yields (911 and 2401 kg/ha, respectively) were recorded with irrigation given at 30 DAS + 60 DAS + 75 DAS (I_3). In case of nitrogen, application of 100% RDN resulted in significantly higher growth and yield. Significantly higher grain and stover yields (906 and 2388 kg/ha, respectively) were recorded under 100% RDN. The maximum net realization (₹ 35232 ha^{-1} and ₹ 35365 ha^{-1}) and BC ratio (1.77 and 1.82) were accrued under irrigation at 30 DAS + 60 DAS + 75 DAS (I_3) and fertilization at 100% RDN, respectively.

Keywords: Grain amaranth, grain yield, irrigation, net realization, nitrogen, stover yield

Introduction

Grain amaranth (*Amaranthus hypochondriacus* L.) belongs to the family Amaranthaceae. The genus Amaranthus includes other species of grain type amaranth, *viz*. *A. peniculatus*, *A. cruentus* and *A. caudatus*. The grain types of amaranthus are thought to be of Central American origin. Grain amaranth reached the pinnacle of its popularity as a staple crop during the *Mayan* and the *Aztec* periods in Central America. European settlers introduced these to the old world during the 19th Century.

Grain amaranth is a potential upcoming subsidiary food crop, considered by many as crop of the future. Certain attributes, like it's higher productivity potential added with substantial quantities of minerals, carbohydrates, fats and proteins comparable with any of the improved cereals, have aroused great interest in development of grain amaranth as a cultivated crop (Desai *et al.*, 2013) [2]. Its input requirements are seemingly much lower than that of any other cereal. Amaranth is a quick growing multipurpose crop suitable for poor soils of semi-arid and seasonal wet areas. This crop is highly resistant to extreme stress conditions. Grain amaranth is a potential upcoming subsidiary food crop, considered by many as crop of the future.

Grain amaranth assumes special significance because of its C_4 - pathway indicating high productivity. It is highly nutritious with higher protein and lysine contents than almost any other cereal (Rana *et al.*, 2017) [12]. Amaranth, as a grain crop, thus seems extremely versatile in climatic adaptation and ranges from low elevation to 2000-3000 m altitude. It seems ideally suited to alternating wet and dry climates where the crop can be planted under warm and moist conditions and can also with stand both drought and low temperature during its later stages.

Water, a scarce and precious commodity, wants judicious use to achieve the goal of increased production per unit volume of water applied. The right time of application of adequate amount of irrigation water with minimum losses is essential for efficient and economic utilization of water resources for higher production (Shinde *et al.*, 2014) [13]. This is especially when water supply is either limited or very costly. Presently, irrigation to grain amaranthus is provided in advertently without understanding the irrigation requirement of the crop. Precisely, one way of increasing production per unit volume of water is to irrigate at critical stages of crop growth, which are more sensitive to water application. Scheduling of irrigation for grain amaranth at various critical growth stages, *i.e.*, from early vegetative growth to grain filling, can record beneficial effects under various agroclimatic conditions. The scheduling of irrigation for grains amaranth, so far, has been restricted to climatic approach (IW/CPE ratio), as a close relationship has been established between the rates of consumptive use and evaporation (Prihar *et al.*, 1974) [11].

Among various other agronomic factors known to augment crop yield, fertilizer management plays a vital role in increasing crop productivity. Out of the three major plant nutrients used as fertilizers, nitrogen ranks first practically all over the world. Nitrogen plays an important role in the synthesis of chlorophyll as well as amino acids, which form the building units of protein and thus contribute to the growth of the plant (Madagoudra *et al*., 2021) [7]. It also helps in early establishment of leaf area capable of photosynthesis and increase root development to enable more efficient use of inadequate supply of nutrients and soil moisture. Significant increase in amaranth seed yield with fertilizer application has been reported (Hauptli and Jain, 1978 and Bressani *et al*., 1987) [4, 1]. Since long, grain amaranth has been cultivated as a marginal crop using local varieties and very little or no fertilizers. This is the main reason for extremely low yield of this crop. So far, not much information has been available on judicious fertilizer use for getting higher yield in the irrigated conditions of the state. In view of the above, this experiment was planned to determine the optimum nitrogen levels and irrigation scheduling for maximum growth and yield of grain amaranth.

Material and Methods

A field experiment was conducted during *rabi* 2017 at college farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari to assess the effect of irrigation and nitrogen levels on growth, yield attributes, yield and economics of grain amaranth. The soil of the experimental site was clayey in texture (62.17%), medium in organic carbon (0.56%), low in available nitrogen (188 kg ha^{-1}), medium in available phosphorus (35 kg ha^{-1}) and available potassium (344 kg ha^{-1}). The soil reaction was slightly alkaline (pH 8.15) with normal electrical conductivity.

In all, twelve treatment combinations, consisting of four levels of irrigation *viz.*, 30 DAS (I_1), 30 DAS + 60 DAS (I_2), 30 DAS + 60 DAS + 75 DAS (I_3) and 0.8 IW: CPE (I_4) and three levels of nitrogen *i.e.*, 50% RDN (N_1), 75% RDN (N_2) and 100% RDN (N_3) were evaluated in factorial randomized block design with three replications. The RDF for the grain amaranth is 60-40-00 NPK kg ha^{-1}. Before the present experiment, Pearl millet was grown in the field and harvested in June and kept fallow prior to grain amaranth sowing. The grain amaranth variety GA-2 was sown on November 22, 2017. The required quantity of clean seeds was mixed with soil by making for uniform sowing of seeds. The sowing was done manually in previously opened furrows at a depth of 2 cm. Seeds were covered properly with the soil and a light irrigation was given carefully in each plot after sowing.

Bio-compost at 5t ha^{-1} was applied on the experimental field before sowing and mixed well. Nitrogen was applied as per the treatments. Common application of 40 kg P_2O_5 ha^{-1} was made as basal. The sources of nitrogen and phosphorus were urea and single super phosphate, respectively. Total four irrigations were given during the crop period.

Data on different growth parameters *viz.*, plant height (cm), dry matter accumulation per plant (g), stem girth (cm) and yield attributes *viz.*, number of lateral spikelets per spike, length of the main inflorescence (cm), test weight (g/cc), grain yield per plant, grain yield (kg/ha) and stover yield (kg/ha) were collected to find out the best treatment. Ten plants from each plot were selected randomly to study these parameters. Net realization (₹ ha^{-1}) was calculated by deducting the cost of cultivation from the gross returns (₹ ha^{-1}).

Results and Discussion

The results of the present study as well as relevant discussion have been summarized under following heads:

Growth parameters

The data pertaining to growth parameters of grain amaranth *viz.*, plant height (cm), dry matter accumulation per plant (g), stem girth (cm) are presented in Table 1. The results revealed that application of irrigation at 30 DAS + 60 DAS + 75 DAS (I_3) produced taller plants as compared to 30 DAS (I_1), 30 DAS + 60 DAS (I_2) and 0.8 IW: CPE (I_4). Significantly highest plant height (190.56 cm) at harvest was observed under irrigation at 30 DAS + 60 DAS + 75 DAS (I_3). The dry matter accumulation improved with the advancement of plant towards maturity. The highest dry matter accumulation at harvest (61.72 g $plant^{-1}$) was recorded under irrigation at 30 DAS + 60 DAS + 75 DAS (I_3). Similar findings were observed by Kumar *et al.* (2011) [6] and Singh *et al*. (2012) [12].

The levels of application of nitrogen also had a significant effect on almost all the growth parameters of grain amaranth. Application of nitrogen in three levels, 50% RDN, 75% RDN and 100% RDN recoded significantly highest plant height (198.08 cm) at harvest. The maximum dry matter accumulation (60.80 g $plant^{-1}$) was obtained with application of 100% RDN. The higher dry matter accumulation was due to higher nitrogen supply at the initial growth stages which had increased the vegetative growth and accelerated cell division and cell elongation which ultimately resulted in luxuriant growth of the crop. The results were in line with the findings of Madagoudra *et al*. (2021) [7] in maize and Patel *et al.* (2012) [10] in grain amaranth.

Yield attributes and yield

The yield attributing characters such as length of the main inflorescence (cm), number of lateral spikelets/spike and test weight (g/cc) did not influence significantly due to irrigation.

Grain and stover yields were significantly influenced by different irrigations. The results presented in Table 2 inferred that irrigation had significant effect on grain and stover yields. I_3 (30 DAS + 60 DAS + 75 DAS) recorded significantly higher grain and stover yields (911 and 2401 kg ha^{-1}, respectively) than I_1 (730 and 2047 kg ha^{-1}, respectively). The increase in grain and stover yields might be due to remarkable improvement in the various growth parameters such as plant height, stem girth and dry matter accumulation resulted in higher grain and stover yields. Similar observations also recorded by Patel *et al.* (2005) [9], Kumar *et al.* (2011) [6], Singh *et al.* (2012) [12], Solanki *et al.* (2016) [15] and Sushma *et al.* (2017) [16] in case of grain and stover yield.

Nitrogen levels significantly influenced the yield attributing character such as length of the main inflorescence (cm) and test weight (g). While, other character number of lateral spikelets per spike did not influence significantly due to nitrogen levels. The result revealed that treatment N_3 (100% RDN) registered higher values as compared to treatment N_1

(50% RDN) for yield attributing characters. Significantly longer length of inflorescence and test weight were observed in N_3 (100% RDN) as compared to N_1. The results presented in Table 2 inferred that nitrogen levels had significant effect on grain and stover yields. N_3 (100% RDN) recorded significantly higher grain and stover yields (906 and 2388 kg ha^{-1}, respectively) than N_1. The increase in grain and stover yields might be due to remarkable improvement in the yield attributes such as length of main inflorescence and test weight and better development of various growth parameters such as plant height, number of leaves per plant and dry matter accumulation resulted in higher grain and stover yields. The results corroborated the findings of Parmar and Patel (2009) [8], Keraliya *et al.* (2017) [5], Dubey *et al.* (2018) [3] and Patel *et al.* (2012) [10].

Economics

The economic analysis of the data revealed that among different irrigation levels (Table 3), I_3 (30 DAS + 60 DAS + 75 DAS) secured maximum net profit (35232 ₹ ha^{-1}) and B:C ratio (1.77) while, I_1 (30 DAS) obtained minimum net profit (25057 ₹ ha^{-1}) and B:C ratio (1.31). This might be due to higher grain and stover yields of crop with treatment I_3 (30 DAS + 60 DAS + 75 DAS). These results are inconformity with those reported by Patel *et al.* (2005) [9] as well as Sushma *et al.* (2017) [16] in grain amaranth.

The economic analysis of the data revealed that among different nitrogen levels (Table 3), N_3 (100% RDN) secured maximum net profit (35365 ₹ ha^{-1}) and B:C ratio (1.82) while, N_1 (50% RDN) obtained minimum net profit (28092 ₹ ha^{-1}) and B:C ratio (1.47). This might be due to higher grain and stover yields of crop with treatment N_3 (100% RDN). These results are inconformity with those reported by Patel *et al.* (2012) [10], Keraliya *et al.* (2017) [5] as well as Dubey *et al.* (2018) [3] in grain amaranth.

Table 1: Effect of irrigation and nitrogen levels on growth of grain amaranth.

Treatments	Plant height (cm) At harvest	Dry matter accumulation at harvest (g plant^{-1})	Stem girth (cm)
A. Irrigation (I)			
I_1: 30 DAS	161.00	54.42	4.23
I_2: 30 DAS + 60 DAS	187.78	57.52	4.47
I_3: 30 DAS + 60 DAS + 75 DAS	190.56	61.72	4.85
I4: 0.8 IW: CPE	189.11	58.29	4.66
S.Em ±	7.76	1.64	0.13
CD (P = 0.05)	22.76	4.80	0.37
B. Nitrogen (N)			
N_1: 50% RDN	168.25	55.42	4.31
N_2: 75% RDN	180.00	57.74	4.60
N_3: 100% RDN	198.08	60.80	4.75
S.Em ±	6.72	1.42	0.11
CD (P = 0.05)	19.71	4.16	0.32
C. Interaction (I x N)			
CD (P = 0.05)	NS	NS	NS
CV%	12.79	8.47	8.39

Table 2: Effect of irrigation and nitrogen levels on yield attributes and yield of grain amaranth

Treatments	Length of the main inflorescence (cm)	Number of lateral spikelets per spike	Test weight (g)	Grain yield plant^{-1} (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
A. Irrigation (I)							
I_1: 30 DAS	161.00	54.42	4.23	4.34	730	2047	26.3
I_2: 30 DAS + 60 DAS	187.78	57.52	4.47	4.78	800	2089	27.8
I_3: 30 DAS + 60 DAS + 75 DAS	190.56	61.72	4.85	5.14	911	2401	27.7
I4: 0.8 IW: CPE	189.11	58.29	4.66	4.95	883	2280	28.0
S.Em ±	7.76	1.64	0.13	0.19	38	92	1.2
CD (P = 0.05)	22.76	4.80	0.37	0.56	110	270	NS
B. Nitrogen (N)							
N_1: 50% RDN	168.25	55.42	4.31	4.54	780	2076	27.3
N_2: 75% RDN	180.00	57.74	4.60	4.73	808	2148	27.5
N_3: 100% RDN	198.08	60.80	4.75	5.14	906	2388	27.6
S.Em ±	6.72	1.42	0.11	0.16	32	80	1.1
CD (P = 0.05)	19.71	4.16	0.32	0.48	95	234	NS
C. Interaction (I x N)							
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS
CV%	12.79	8.47	8.39	11.89	13.54	12.52	13.73

Table 3: Effect of irrigation and nitrogen levels on cost of cultivation, gross realization, net realization and B:C ratio of grain amaranth

Treatment	Yield (kg ha^{-1})		Total cost (₹ ha^{-1})	Gross realization (₹ ha^{-1})	Net realization (₹ ha^{-1})	B:C ratio
	Grain yield	Stover yield				
A. Irrigation (I)						
I_1: 30 DAS	730	2047	19152	44209	25057	1.31
I_2: 30 DAS + 60 DAS	800	2089	19530	48418	28888	1.48
I_3: 30 DAS + 60	911	2401	19908	55140	35232	1.77

DAS + 75 DAS						
I_4: 0.8 IW: CPE	883	2280	19908	53436	33528	1.68
B. Nitrogen (N)						
N_1: 50% RDN	780	2076	19123	47215	28092	1.47
N_2: 75% RDN	808	2148	19298	48910	29611	1.53
N_3: 100% RDN	906	2388	19473	54838	35365	1.82

Conclusion

The findings of the experimentation indicated that irrigation at 30 DAS + 60 DAS + 75 DAS along with the application of 100% RDN (60 kg N ha^{-1}) discernibly improved plant growth, yield attributes and yield of *rabi* grain amaranth *var.* GA-2. The net realization was also higher for the above treatment combination as compared to rest of the treatment combinations.

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