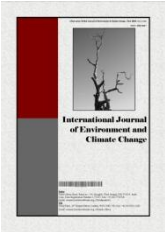


International Journal of Environment and Climate Change

12(10): 870-881, 2022; Article no.IJECC.87049
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Assessment of Promising Diverse Germplasm Accessions for Stability with Respect to Yield and Its Attributing Traits in Vegetable Amaranth

T. N. Lakshmidevamma [a*], Sanjeev K. Deshpande [a], R. C. Jagadeesha [b], B. R. Patil [a], Ramangouda V. Patil [c] and Kiran Mirajkar [d]

[a] Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad, Karnataka, India.
[b] Department of Genetics and Plant Breeding, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shimoga, Karnataka, India.
[c] Department of Horticulture, University of Agricultural Sciences, Dharwad, Karnataka, India.
[d] Department of Biochemistry, University of Agricultural Sciences, Dharwad, Karnataka, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1030875

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/87049

Original Research Article

Received 07 March 2022
Accepted 14 May 2022
Published 08 June 2022

ABSTRACT

Vegetable amaranth is one of the popular leafy vegetable that occupies a prominent place in India owing to its high nutritive value and fast growing ability. The presence of considerable genetic variability in the amaranth along with very high phenotypic plasticity demands the development of stable genotypes to secure sustainable production. The present research was carried out to quantify the effect of genotype x environment interaction on the performance of 30 identified promising genotypes of vegetable amaranth. The experiment was laid out in the Randomized Complete Block Design with three replications at three locations *viz*., Arabhavi, Dharwad and Bagalkot during *kharif* 2018-19. Stability analysis was done as per the linear regression model described by Eberhart and Russell [1] that measures the genotypic response to changing environments. Variance due to environment + (genotype x environment) was significant for four of the studied traits *viz*., fresh green yield per hectare, fresh green yield per plant, plant height and leaf length which specified the existence of noteworthy interaction between the genotypes and the

*Corresponding author: E-mail: lakshmi88tn@rediffmail.com, lakshmi88tn@gmail.com;

environmental conditions. The accessions, VA-16, CO-1, IC-553719 and IC-469645 have been identified as the high yielding stable genotypes for fresh green yield. Stable accessions for plant height include IC-536714, IC-541407, Arka amaranth, IC-469579 and IC-553719 and for leaf length were CO-1, IC-550143, IC-551472, IC-536714 and IC-469722. Further, some stable accessions for yield and its attributes were indicated that can be, commercialised or used in future breeding programs.

Keywords: Vegetable amaranth; stability; regression co-efficient; environment index.

1. INTRODUCTION

Amaranthus (*Amaranthus* spp. L.) is considered as one of the ancient food crops of the world that had disappeared for centuries, but received a greater attention nowadays as a potential futuristic crop for its excellent nutritional value [2]. The genus Amaranthus consists of more than 70 species, wherein some are cultivated as grain, leafy vegetable, forage as well as ornamental species. Among these, vegetable amaranth is the most popular leafy vegetable that occupies a prominent place in India owing to its rich nutritional value and fast growing ability contributing for high foliage yield potential within a short duration. Adequate levels of bioactive components make vegetable amaranthus one of the top five vegetables with enhanced antioxidant levels [3]. The leaves contain 17.5 to 38.3% protein on dry weight basis [4] and serve as an inexpensive source of dietary fibre, protein, vitamins and a wide range of minerals [5]. The tender leaves and stems are rich in vitamin A and C, calcium and iron. One hundred grams of cooked vegetable amaranth can contribute to 45% of daily Vitamin A requirement [6]. Amaranths contain three times higher vitamin C and calcium compared to that of spinach and 18 times more vitamin A, 13 times more vitamin C, 20 times more calcium and 7 times more iron than lettuce [6]. Besides its immense nutritional value, vegetable amaranth is known to be grown in varied as well as marginal environments owing to its ability to withstand acute drought conditions, thus contributing for climate change mitigation [7].

Development of superior genotypes giving consistent performance in many variable environments is the major objective of plant breeding and selection programmes [8]. Selection of crop varieties that are more suited to diverse environments has direct bearing on the spread of the variety, productivity and total production of the crop. Suitable stable genotypes are always sought after for expanding the area under vegetable amaranth. Inconsistent genotypic responses to environmental factors from location to location and year to year lead to significant genotype-environment (GXE) interactions [9]. Amaranth crop is more sensitive to environmental variations and the crop yields fluctuate across agro-ecological niches. Stability of yield and related traits is greatly affected by the continued variation in climatic conditions and thus it is essential to identify stable performing genotypes across the environments. Hence, G X E interaction forms a significant entity in deciding the worthiness of a crop cultivar [10].

Varietal plasticity to environmental fluctuations is crucial for the stabilization of crop production both over regions and years and so, a significant way in identifying stable genotypes is to subject the selected promising genotypes to multi-environmental testing. Adaptability, the ability of a genotype to exhibit stable performance in different environments need to be measured in terms of phenotypic stability [11,12]. The generated information on the nature and magnitude of GXE interactions in respect of yield and its component characters through stability analysis can contribute for the identification of location specific and widely adaptable genotypes [13]. However, earlier studies on the assessment of genotype X interaction and identification of widely adaptable genotypes in vegetable amaranth is very limited. It is therefore important to quantify GXE interaction to develop stable cultivars for enhanced fresh green yield levels of the exceptionally nutritional vegetable Amaranth. Further, such information is vital for expanding this crop in the rural areas. The presence of considerable genetic variability in the amaranth coupled with very high phenotypic plasticity necessitates the development of stable genotypes for secured and sustainable crop production. Hence in the present investigation, the 30 selected pure breeding lines of vegetable amaranth identified based on their performance for yield and yield attributes during summer-2018 and *kharif*-2018 were evaluated across three locations with varied agro-climatic conditions and subjected to stability analysis. Identification of promising stable genotypes contribute to the popularization of vegetable amaranth as a potential crop with rich nutrition.

2. MATERIALS AND METHODS

Thirty vegetable amaranth accessions selected out of 85 evaluated germplasm accessions based on their *per se* performance for fresh green yield and its attributes during summer-18 and *kharif*-18 were considered for stability studies. These genotypes were evaluated across the three diverse agro-ecological locations *viz*., Arabhavi, Dharwad and Bagalkot, in randomized complete block design with three replications during *kharif*-18-19. Each accession was raised in one square meter plot with a row spacing of 25 cm. The crop was grown in accordance with the recommended set of cultivation practices. The Dharwad location coming under Northern transition zone (Zone VIII) of Karnataka is situated at 15°26'N latitude and 70°26'E longitude with an altitude of 678 m above mean sea level. Soils are deep black fertile soil with an average annual rainfall of about 770.95 mm during cropping period. The monthly minimum and maximum temperatures were 13.90°C to 36.20°C respectively. Arabhavi is located in Northern dry zone (Zone III) of Karnataka at 16°15' N latitude and 74°81' E longitude with an altitude of 612 m above sea level. The soils are sandy loam type with an average rainfall of 298 mm during cropping period in addition to irrigation source from Ghataprabha Left Bank Canal [GLBC]. The monthly minimum and maximum temperature were 13.20°C to 37.20°C respectively. Bagalkot is situated in Northern dry zone (Zone VIII) of Karnataka at a latitude of 16°11'N and longitude of 75°42'E and at an altitude of 537 m above mean sea level. The soil are medium red sandy loam and the average annual rainfall during cropping period was about 542.80 mm. The monthly minimum and maximum temperatures were 14.00°C to 35.75°C respectively.

Ten plants were selected randomly from each plot for recording data at the harvestable stage of the plant. The observations on fresh green yield and its attributing traits *viz.,* fresh green yield per hectare (quintols), fresh green yield per plant (grams), leaf to stem ratio, plant height (cm), number of leaves per plant, stem diameter (mm), leaf length (cm), leaf width (cm) and petiole length (cm) were recorded at the three locations and the data was subjected to pooled analysis as the variances were homogenous. Stability analysis was done as per the linear regression model described by Eberhart and Russell [1] using INDOSTAT software version 9.2 to know the extent of linear and nonlinear components of variation. The linear regression is considered as a measure of genotypic response to changing environments. This model is widely used for its simplicity and reliability which envisages a genotype to be stable when the regression coefficient is equal to one (bi=1) and there is non-significant deviation from regression coefficient as close to zero (S^2d_i =0) along with higher mean performance. The linear regression coefficient equal to unity (bi=1) indicates average sensitivity to environmental changes; a regression coefficient of less than unity (bi < 1), indicates above average sensitivity to environmental fluctuations and better adaption to unfavourable environments; a regression coefficient of greater than unity (bi>1), indicates higher sensitivity to environmental changes, but specifically adapted to favourable environments. Deviation from regression if non-significant (S^2d_i =0), the performance of genotypes for a given environment might be accurately predicted.

3. RESULTS AND DISCUSSION

Performance of the 30 vegetable amaranth genotypes across three locations pertaining to nine yield related traits was assessed and the data was subjected to stability analysis after confirming significant G x E interactions and the variance was segregated as per Eberhart and Russell [1] model. The extent of linear and nonlinear components of variation that provide information on predictable and unpredictable sources of variation were assessed. Pooled analysis for stability for these yield related traits is presented in Table 1.

Significant differences among the genotypes were observed for fresh green yield per hectare and the other studied traits. Further, the variance due to environments (linear) was also significant for all the traits except for stem diameter which projected that the three environments varied significantly. However, the variance due to environment + (genotype x environment) was significant for only four traits *viz*., fresh green yield per hectare, fresh green yield per plant, plant height and leaf length which specified the existence of noteworthy interaction between the genotypes and the environmental conditions. So, the genotypes regressed distinctly in varying environments for these traits that interacted with the environment and thus have been assessed further to identify stable genotypes. Significant variance due to pooled deviation was detected which inferred that the deviation from linear regression also contributed strikingly towards the differences in stability of genotypes. Thus, both linear (predictable) and non-linear (un-predictable) components significantly contributed to genotype x environment interactions.

3.1 Stability Analyses for Fresh Green Yield

In the present study, the mean, linear regression (bi) and deviations from regression (S^2di) for each genotype were considered for testing the genotype response and stability. The magnitude of regression coefficient and deviations from regression varied from genotype to genotype. The observed yield levels across the three locations, over all mean value, regression coefficient (bi) and deviation from regression (S^2di) for fresh green yield per hectare are presented in Table 2. The mean performance for fresh green yield across the locations as well as the overall mean are graphically presented in the Fig. 1. It is evident in the investigation that the genotypes showed differential responses to adaptability under different environments (locations) as revealed from their mean performance, bi and S^2di. García-Pereyra et al. [14] studied genotype × environment interaction and stability of five genotypes of amaranth and indicated the differential behaviour of genotypes in various localities. The negative and non-significant bi value and non-significant S^2di value was also revealed by Varalakshmi et al. [15]. Fresh green yield per hectare recorded across the three environments ranged from 9.28 (IC-551472) to 18.42 tons (VA-16) tons with a mean of 12.37 tons. VA-16 was the most promising genotype in all the three locations with a mean of 18.42 tons followed by CO-1 (16.53 tons) and IC-541407 (15.49 tons).

According to Eberhart and Russel [1] an ideally adopted genotype is the one having higher mean value, regression coefficient near to unity(bi=1) with least deviation from regression (S^2di=0). The differences in regression co-efficient (bi) values reflected that all the genotypes respond differently to different environments. In the present study, the mean and deviations from regression (S^2di) for each genotype were considered for stability and linear regression (bi) was used for testing the genotype response. The magnitude of regression coefficient and deviations from regression varied from genotype to genotype. In the present study, among the 30 accessions, the genotype VA-16 with a mean yield of 18.42 tons per hectare, unit regression co-efficient (bi=1.28) and non-significant deviation of regression co-efficient from zero (S^2di= -0.24), was the most promising stable genotype identified across the locations. In addition, CO-1 with a mean of 16.53 tons (bi=0.63, S^2di=-0.56); IC-553719 (mean=14.17 tons, bi=1.38, S^2di=1.16) and IC-469645 (mean=13.71 tons, bi=1.63, S^2di=-0.07) were also reported as high yielding stable genotypes as they registered significantly higher yield levels than the overall mean (12.37 tons) with the regression coefficient near to unity and non-significant deviation of regression co-efficient from zero. These genotypes revealed average environment sensitivity signifying their adaptability to varying environments. Stable genotypes for fresh green yield have also been specified in the earlier studies [16], Shudhir et al. (2003), Kishore et al. [17], Dhanapal, (2009), Yarnia [18], Varalakshmi et al. [15], Khurana et al. [19], and Dewan et al. [20]. Stable genotypes at all the locations as well as specific location are presented in the Table 3 and Fig. 2.

On the other hand, the accessions *viz*., IC-551497 (15.27 tons), IC-469579 (14.66 tons), even though recorded higher yield than overall population mean, but all these genotypes had a regression coefficient greater than unity (b_i >1) which shown their high sensitivity to environmental changes and better response to favourable environments [16]. In addition, two accessions, *viz*., IC-541407 (15.49 tons) and IC-553731 (13.61 tons) with higher fresh green yield per hectare than population mean across the locations with unit regression coefficient (bi = 0.74 & -0.71), which indicated their low response to environmental conditions. Nevertheless, the deviation of regression value was significant which indicated their instability *i.e*., genotype performance could not be predictable [20]. Among these genotypes, IC-553731 could be considered as the high yielding stable genotype under poor environments as it had higher mean value but with, negative insignificant bi value and non-significant S^2di value from zero. Several genotypes showed non-significant bi value and non-significant S^2di values for this trait which was also reported by Shukla and Singh [16] in vegetable amaranth; Similar results in grain amaranth for stem weight was observed by Ejieji and Adeniran [21] and Varalakshmi et al. [15].

Table 1. Pooled analysis of variance for stability parameters associated with fresh green yield and yield attributes in vegetable amaranth

Eberhart and Russel model [1]

Source of variation	*d.f.*	Fresh green yield per hectare (tons ha^{-1})	Fresh green yield per plant (g)	Leaf to stem ratio	Plant height (cm)	Number of leaves per plant	Stem diameter (mm)	Leaf length (mm)	Leaf width (mm)	Petiole length (mm)
Replication	6	0.59	0.49	0.013	2.37	1.69	0.25	0.14	0.14	0.24
Genotypes (G)	29	14.10**	4.92**	0.243**	15.98**	2.68**	0.65*	2.78**	1.44**	1.28**
Environment + (Genotype X Environment)	60	4.87**	1.35*	0.026	4.26*	1.03	0.25	2.51**	0.16	0.21
Environments (E)	2	49.21**	12.41**	0.222**	25.32**	3.95*	0.21	5.02**	0.39	1.06*
Genotype X Environment (GXE)	58	3.72**	1.19*	0.019	3.83*	0.93	0.25	2.42**	0.15	0.18
Environment (Linear)	1	98.42**	24.82**	0.443**	50.63**	7.90**	0.42	10.05**	0.78*	2.12**
Genotype X Environment (Linear)	29	4.48**	1.34*	0.019	4.57*	0.81	0.20	4.54**	0.16	0.11
Pooled deviation	30	2.12**	0.70**	0.018	2.25**	1.02	0.30**	0.291*	0.14*	0.25*
Pooled error	174	0.56	0.25	0.012	1.46	1.05	0.13	0.16	0.09	0.15
Total	89	7.88	2.51	0.096	8.08	1.57	0.38	3.38	0.58	0.56

** - Significant at 5 % level of significance; ** - Significant at 1 % level of significance*

Table 2. Stability parameters among the promising accessions of vegetable amaranth for fresh green yield per hectare

Sl. No.	Genotype	Fresh green yield per hectare (tons ha^{-1})				b_i	S^2d_i
		Arabhavi	Dharwad	Bagalkot	Grand mean of the genotype		
1	IC-553731	11.93	15.63	13.27	13.61	-0.71	4.80
2	IC-536713	13.37	11.80	9.00	11.39	1.65	0.33
3	IC-553743	13.33	10.60	9.03	10.99	1.70	-0.56
4	IC-551472	10.55	8.90	8.40	9.28	0.87	-0.50
5	IC-536714	18.22	13.73	9.07	13.67	3.53	0.45
6	IC-550143	14.17	10.87	10.03	11.69	1.68	-0.23
7	IC-469694	9.72	8.27	12.93	10.31	-1.04	7.27
8	IC-469645	15.73	13.93	11.47	13.71	1.63	-0.07
9	IC-541407	15.53	17.93	13.00	15.49	0.74	9.81
10	IC-551497	17.60	15.60	12.60	15.27	1.90	0.27
11	IC-469579	19.38	12.47	12.13	14.66	3.01	3.13
12	IC-469658	13.98	10.13	10.07	11.39	1.64	0.71
13	IC-469722	10.02	15.10	10.10	11.74	-0.36	15.96
14	IC-551473	11.75	8.77	8.17	9.56	1.46	-0.21
15	IC-553720	11.13	9.50	13.60	11.41	-0.77	6.03
16	IC-469558	16.45	11.57	12.07	13.36	1.87	2.42
17	IC-553719	15.67	14.93	11.90	14.17	1.38	1.16
18	IC-551461	14.43	8.63	12.83	11.97	0.94	14.47
19	IC-469601	13.38	11.23	8.17	10.93	1.99	0.25
20	IC-536555	11.10	10.17	9.00	10.09	0.80	-0.47
21	VA-3	13.17	10.27	11.03	11.49	0.94	1.03
22	VA-12	12.82	10.77	11.83	11.81	0.48	0.78
23	VA-16	20.70	18.50	16.07	18.42	1.28	-0.24
24	Arka Samraksha	9.27	9.70	10.20	9.72	-0.36	-0.55
25	Arka Varna	9.22	9.80	10.43	9.82	-0.47	-0.54
26	Arka Arunima	12.75	13.20	11.47	12.47	0.42	0.46
27	Arka Suguna	13.72	11.43	11.30	12.15	1.00	-0.18
28	Arka amaranth	13.78	11.63	10.60	12.01	1.27	-0.55
29	CO-1	17.40	16.40	15.80	16.53	0.63	-0.56
30	Pusa Kirti	12.01	13.20	10.67	11.96	0.40	2.13
	C.D 95%	2.465	2.098	1.744			
	C.V. (%)	10.976	10.56	9.518	-		
	Mean	13.74	12.16	11.21	12.37		
	S.E(mean) ±	1.23	1.05	0.87	1.18		
	Mean of bi				1.00		
	S.E. of bi±				0.92		

Population mean – 12.37 tons ha^{-1}

b_i -Regression coefficient; S^2d_i - Mean square deviation from

** - Significant at 5 % level of significance; ** - Significant at 1 % level of significance regression*

Performance of genotypes vary according to the changing environments and thus, the relative ranking of genotypes also vary from environment to environment. However, in this study some genotypes have given consistently better performance across the locations owing to their high buffering ability. Better performing genotypes across the three locations include VA-16, CO-1, IC-541407, IC-551497 and IC-469579 that have given consistent superior performance for fresh green yield per hectare. However, few accessions that have given superior performance specific to each location also been indicated *viz.*, VA-16, IC-469579, IC-536714, IC-551497 and CO-1 in Arabhavi; VA-16, IC-541407, CO-1, IC-553731 and IC-551497 in Dharwad; VA-16, CO-1, IC-553720, IC-553731 and IC-541407 in Bagalkot (Table 4).

Table 3. Stable genotypes across all the environments, favourable and poor environments for fresh green yield in vegetable amaranth

Sl. No.	Genotypes	Grand mean	b_i	S^2d_i
Superior genotypes well adapted to all the environments				
1	VA-16	18.42	1.28	-0.24
2	CO-1	16.53	0.63	-0.56
3	IC-553719,	14.17	1.38	1.16
4	IC-469645	13.71	1.63	-0.07
5	IC-469558	13.36	1.87	2.42
Superior genotypes well adapted to favourable environments				
1	IC-551497	15.27	1.90	0.27
2	IC-469579	14.66	3.02	3.13
3	IC-536714	13.67	3.53	0.45
Superior genotypes well adapted to poor environments				
1	IC-553731	13.61	-0.71	4.80
2	Arka Arunima	12.47	0.43	0.46
Population mean – 12.37 tons ha^{-1}				

Table 4. Environment-wise superior accessions for fresh green yield in vegetable amaranth

Sl. No	Characters	Arabhavi *kharif,* 2018	Dharwad, *kharif,* 2018	Bagalkot, *kharif,* 2018	Across locations
1	Fresh green yield per hectare (tons)	VA-16	VA-16	VA-16	VA-16
		IC-469579	IC-541407	CO-1	CO-1
		IC-536714	CO-1	IC-553720	IC-541407
		IC-551497	IC-553731	IC-553731	IC-551497
		CO-1	IC-551497	IC-541407	IC-469579

3.2 Stability Analyses of Fresh Green Yield Related Traits

Stability of genotypes for yield is the consequence of stability for its component traits [22]. The overall mean values for significantly interacted yield traits, regression coefficient (b_i) and deviation from regression (S^2d_i) of vegetable amaranth genotypes revealing their response to different environments are shown in Table 5. Across the environments, fresh green yield per plant ranged from 3.77 (Arka Samraksha) to 9.22 grams (CO-1) with an average of 6.43 grams; Plant height ranged from 16.68 (IC-536555) to 25.75 cm (CO-1) with a mean of 20.45 cm; Leaf length ranged from 4.29 (Arka Samraksha) to 7.99 cm (CO-1) with an average of 5.86 cm.

Stable accessions that have recorded higher mean values with unit regression co-efficient and insignificant deviation of regression co-efficient from zero have been specified in the study for the yield attributes *viz*., CO-1 (9.22 g $plant^{-1}$), VA-16 (8.75 g $plant^{-1}$), VA-12 (7.07 g $plant^{-1}$), IC-553719 (6.88 g $plant^{-1}$) and Arka amaranth (6.86 g $plant^{-1}$) for fresh green yield per plant; IC-536714 (21.68 cm), IC-541407 (23.63 cm), Arka amaranth (22.15 cm), IC-469579 (21.00 cm) and IC-553719 (20.81 cm) for plant height (in line with Khurana et al*.* [19]); CO-1 (7.99 cm), IC-550143 (7.27 cm), IC-551472 (6.17 cm), IC-536714 (5.91 cm) and IC-469722 (6.02 cm) for leaf length (Also reported by Khurana et al*.* [19]).

However, many accessions even though had higher mean value with non-significant deviation of regression co-efficient, but had regression co-efficient more than one (bi>1). These genotypes include, IC-551497 (8.03 g $plant^{-1}$), IC-469579 (8.00 g $plant^{-1}$), IC-469558 (7.76 g $plant^{-1}$) and IC-550143 (7.00 g $plant^{-1}$) for fresh green yield per plant; CO-1 (25.75 cm), IC-469601(23.74 cm), IC-469645 (23.02 cm) and IC-469558 (22.40 cm) for plant height; VA-16 (7.13 cm), IC-469645 (6.71 cm), IC-553731 (6.49 cm) and IC-469579 (6.27 cm) for leaf length. This revealed their vulnerability to fluctuating environments. Further, the accessions IC-541407, IC-469722 and IC-553731 even with higher fresh green yield per plant, had regression co-efficient lower than unity which revealed their better performance and suitability to poor environments. Likewise, the accessions IC-551461, IC-550143, Arka Arunima and Pusa Kirti with better mean performance for plant height and IC-536713, IC-469658, Arka Arunima and IC-553743 for leaf length, were revealed to be more adopted to poor environments. Thus, these genotypes are to be tested further in different locations to identify a suitable environment for its adaptability. Studies by Shukla and Singh [16]; Varalakshmi et al. [15] and Dewan et al. [20] also identified vegetable amaranth genotypes for wider adaptability across a range of climatic conditions.

Wide, specific and poorly adaptable vegetable amaranth genotypes with respect to yield and yield attributes are presented in the Table 6.

Some accessions in the study revealed wide adoptability for yield and its attributes like VA-16 for fresh green yield per hectare and per plant; CO-1 for green yield and leaf length; IC-553719 for green yield and plant height; Arka amaranth for fresh green yield and plant height. Negative association and lack of association among important yield determining characters sometimes make it difficult to identify stable genotypes for combination of traits. However, the present study revealed some stable accessions for combination of traits *i.e.,* VA-16, CO-1, IC-553719.

Table 5. Stability parameters among the promising accessions of vegetable amaranth for yield attributes

Sl. No.	Characters	Fresh green yield per plant (g)			Plant height (cm)			Leaf length (cm)		
	Accession	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**
1	IC-553731	6.64	-0.20	0.86	19.51	0.92	-0.09	6.49	3.01	0.34
2	IC-536713	6.11	1.82	-0.24	21.76	1.96	-1.46	7.29	-0.99	1.13
3	IC-553743	5.67	1.67	-0.20	20.42	1.66	-0.37	5.94	-0.10	0.02
4	IC-551472	5.06	1.36	0.20	16.90	-0.25	0.87	6.17	1.48	-0.16
5	IC-536714	6.68	2.54	-0.25	21.68	1.69	3.63	5.91	1.43	-0.16
6	IC-550143	7.00	2.39	-0.16	21.72	0.66	2.99	7.27	1.07	-0.13
7	IC-469694	6.46	-1.04	0.41	18.93	-2.20	-1.15	5.69	-2.07	-0.05
8	IC-469645	6.85	1.75	0.53	23.02	2.21	0.10	6.71	2.94	0.02
9	IC-541407	7.08	0.19	0.05	23.63	1.62	-1.25	5.01	-1.23	-0.10
10	IC-551497	8.03	2.03	-0.19	21.70	2.62	0.69	5.09	1.71	-0.12
11	IC-469579	8.00	2.38	0.38	21.00	1.79	5.87	6.27	2.21	0.28
12	IC-469658	5.02	0.67	-0.07	18.05	0.99	-1.49	6.18	0.33	-0.14
13	IC-469722	6.86	0.39	5.77	19.74	1.07	29.51	6.02	1.25	-0.13
14	IC-551473	4.71	0.51	-0.17	16.14	2.05	5.95	4.58	1.77	-0.12
15	IC-553720	5.39	-1.76	1.13	18.09	-2.40	6.99	5.88	0.24	1.86
16	IC-469558	7.76	3.70	0.30	22.40	3.68	1.30	5.54	1.60	-0.15
17	IC-553719	6.88	1.49	0.39	20.81	1.81	-1.38	5.27	1.55	-0.16
18	IC-551461	6.08	0.84	2.57	21.87	-0.93	-1.50	5.13	0.13	-0.02
19	IC-469601	6.20	1.96	-0.26	23.74	1.90	-1.16	4.78	2.46	0.49
20	IC-536555	4.48	0.63	-0.21	16.68	0.80	-0.85	5.26	0.47	-0.13
21	VA-3	6.25	2.11	0.18	17.51	0.83	-1.35	4.92	1.39	-0.08
22	VA-12	7.07	0.62	0.03	18.87	0.68	-0.75	5.83	2.74	0.20
23	VA-16	8.75	1.48	-0.23	17.55	0.47	-1.39	7.13	2.87	0.00
24	Arka Samraksha	3.77	-0.73	-0.25	20.71	2.25	10.39	4.29	0.39	-0.15
25	Arka Varna	4.42	-1.02	0.00	19.49	-1.07	3.28	5.24	0.20	0.78
26	Arka Arunima	7.64	0.20	1.05	21.34	-0.04	-0.49	6.78	-0.51	0.21
27	Arka suguna	5.85	0.74	-0.21	20.30	-0.32	-0.88	5.68	-0.46	0.45
28	Arka amaranth	6.86	1.66	-0.23	22.15	1.88	1.08	5.90	1.87	-0.10
29	CO-1	9.22	0.93	-0.25	25.75	3.12	2.55	7.99	1.71	-0.11
30	Pusa Kirti	6.15	0.70	2.35	22.02	0.55	6.22	5.50	0.54	0.09
	Population mean	6.43			20.45			5.86		
	S.E(mean)±	0.59			1.36			0.38		

Environmental index (Table 7) indicated positive influence at Arabhavi for fresh green yield and its attributing traits compared to low to negative environmental index at Dharwad and Bagalkot respectively. Average yields across the locations indicated that the fresh green yield per hectare was comparatively high at Arabhavi location (13.74 tons) which was also found to be higher than the grand mean which signified its favourable environment compared to Dharwad and Bagalkot locations. In addition, the positive environmental index (I_j) for majority of the traits studied was observed at Arabhavi location, whereas for fresh green yield, plant height and leaf length at Dharwad location. On the other hand, negative environmental index (I_j) was noticed for all the traits at Bagalkot location. This reflected Arabhavi as the favourable environment for the better expression of these traits leading to superior performance of vegetable amaranth genotypes. Though many genotypes were alike, genetic differences due to their different genetic backgrounds among the lines tested existed. This in association with the varied environmental factors like temperature, water availability and soil conditions in the studied locations caused further differences in phenotypic observations [23].

Table 6. Wide, specific and poorly adoptable vegetable amaranth genotypes with respect to yield and yield attributes

Traits	Well adapted to all environments [bi=1, S^2di=0, high mean]	Adapted to favourable environments [bi>1, S^2di=0, high mean]	Adapted to poor environments [bi<1, S^2di=0, high mean]
Fresh green yield per hectare (tons)	VA-16, CO-1, IC-553719, IC-469645, IC-469558	IC-551497, IC-469579, IC-536714	IC-553731, Arka Arunima
Fresh green yield per plant (g)	CO-1, VA-16, VA-12 IC-553719, Arka amaranth	IC-551497, IC-469579, IC-469558, IC-550143	Arka Arunima, IC-541407, IC-469722, IC-553731
Plant height (cm)	IC-541407, Arka amaranth, IC-536714, IC-469579, IC-553719	CO-1, IC-469601 IC-469645, IC-469558, IC-536713, IC-551497	Pusa Kirti, IC-551461, IC-550143, Arka Arunima
Leaf length (cm)	CO-1, IC-550143, IC-551472, IC-536714, IC-469722	VA-16, IC-469645, IC-553731, IC-469579, Arka amaranth	IC-536713, IC-469658, Arka Arunima, IC-553743

Table 7. Mean performance and environmental index of three environments for nine traits in vegetable amaranth

Traits/ Environments	Mean performance			Grand mean	Environment Index		
	E1	E2	E3		E1	E2	E3
Fresh green yield per hectare (tons)	13.74	12.16	11.21	12.37	1.37	-0.21	-1.16
Fresh green yield per plant (g)	7.08	6.43	5.79	6.43	0.65	-0.01	-0.64
Leaf to stem ratio	1.54	1.50	1.37	1.47	0.07	0.03	-0.10
Plant height (cm)	21.09	20.84	19.42	20.45	0.64	0.39	-1.03
Number of leaves per plant	10.15	10.18	9.54	9.96	0.19	0.23	-0.42
Stem diameter (mm)	4.58	4.41	4.51	4.50	0.08	-0.09	0.01
Leaf length (cm)	6.05	5.95	5.57	5.86	0.19	0.10	-0.29
Leaf width (cm)	4.19	4.15	3.98	4.11	0.09	0.04	-0.13
Petiole length (cm)	4.40	4.58	4.20	4.39	0.01	0.19	-0.19

E1 = kharif 2018 at Arabhavi; E2 = kharif 2018 at Dharwad; E3 = kharif 2018 at Bagalkot

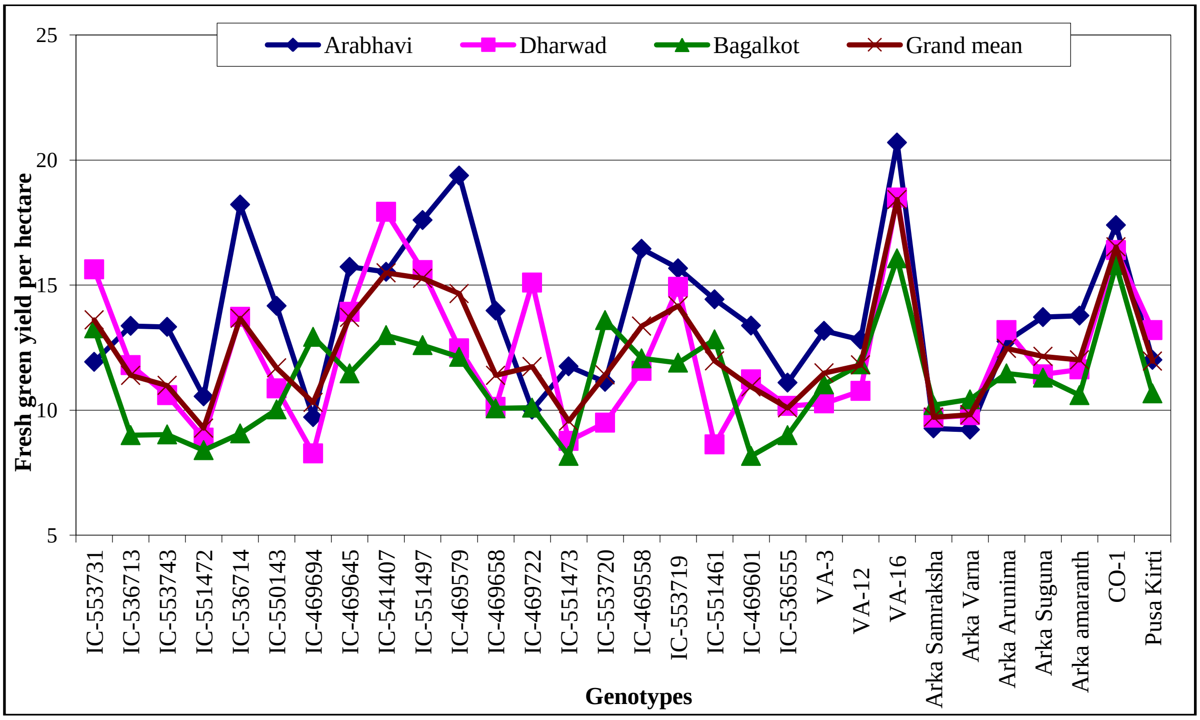
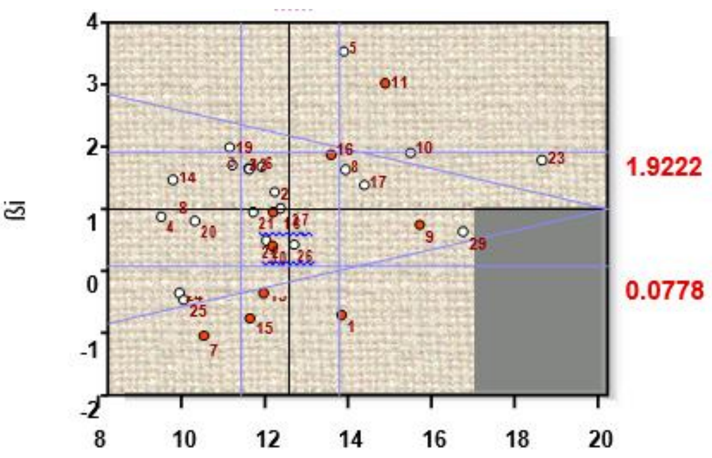


Fig. 1. Performance of vegetable amaranth genotypes across the three locations for fresh green yield per hectare



Fresh green yield per hectare (tons)

Fig. 2. Stable vegetable amaranth genotypes for fresh green yield per hectare across the three locations

4. CONCLUSION

In vegetable amaranth, fresh green yield is the most important breeding trait and identification of stable accessions with higher yield levels is of immense value. In the present study, among the 30 genotypes, the accessions VA-16, CO-1, IC-553719 and IC-469645 have been identified as the high yielding stable genotypes as they have registered high yield levels with significant bi value and non-significant deviation from regression near zero. Further, some stable accessions revealed wide adoptability for yield and its attributes like VA-16 for fresh green yield per hectare and plant; CO-1 for green yield and leaf length; IC-553719 and Arka amaranth for fresh green yield and plant height. A detailed stability assessment of the genotypes for yield related traits is essential before they are utilized in breeding programs or for commercial cultivation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Eberhart ST, Russell WA. Stability parameters for comparing varieties. Crop Sci. 1966;6(1):36-40.
2. Wu H, Sun M, Yue S, Sun H, Cai Y, Huang R, Brenner, D and Corke, H. Field evaluation of an Amaranthus genetic resource collection in China. Genet. Resour. Crop Evol. 2000;47(1):43-53.
3. Das S. Amaranths: The crop of great prospect. In Amaranthus: A Promising Crop of Future. Springer, Singapore. 2016;13-48.
4. Srivastava R. Nutritional quality of some cultivated and wild species of *Amaranthus* L. International Journal of Pharmaceutical Sciences and Research. 2011;2(12): 3152.
5. Shukla S, Bhargava A, Chatterjee A, Srivastava A, Singh SP. Genotypic variability in vegetable amaranth (*Amaranthus tricolor* L.) for foliage yield and its contributing traits over successive cuttings and years. Euphytica. 2006; 151(1): 103-110.
6. Mulokozi G, Hedrén E, Svanberg U. In vitro accessibility and intake of β-carotene from cooked green leafy vegetables and their estimated contribution to vitamin A requirements. Plant Foods for Human Nutrition. 2004;59(1):1-9.
7. Jacobsen SE, Sorensen M, Pedersen SM, Weiner J. Using our agrobiodiversity: Plant-based solutions to feed the world. Agron. Sustain. Dev. 2015;35(4): 27-35.
8. Pour-Aboughadareh A, Yousefian M, Moradkhani H, Poczai P, Siddique KH, STABILITYSOFT: A new online program to calculate parametric and non-parametric stability statistics for crop traits. Applications in Plant Sciences. 2019; 7(1):e01211.
9. Baker RJ. Tests for crossover genotype x environment interactions. Canadian Journal of Plant Science. 1988;68:405–410.
10. Kang MS. Genotype–Environment Interaction: Progress and Prospects. Quantitative Genetics, Genomics, and Plant Breed. 2002;219.
11. Tomkins JP, Shipe ER. Environmental adaptation of long-juvenile soybean cultivars and elite strains. Agron. J. 1997; 89(2):257-262.
12. Van Eeuwijk FA, Bustos-Korts DV. Malosetti M. What should students in plant breeding know about the statistical aspects of genotype× environment interactions?. Crop Science. 2016;56(5): 2119-2140.
13. Admassu S, Nigussie M, Zelleke H. Genotype-environment interaction and stability analysis for grain yield of maize (*Zea mays* L.) in Ethiopia. Asian J. Plant Sci. 2008;7(2):163-169.
14. García-Pereyra J, Valdés-Lozano CGS, Alejandre-Iturbide G, Villanueva Fierro I, Alvarado Gómez OG. Interacción genotipo x ambiente y análisis de estabilidad en genotipos de amaranto (*Amaranthus* spp.). Phyton (Buenos Aires). 2011;80(2): 167-173.
15. Varalakshmi B, Kesava Rao V, Naik G. Antioxidant-rich amaranth varieties, Arka Samraksha and Arka Varna. J. Hortl. Sci. 2011;6(2):163-165.
16. Shukla S, Singh SP. Stability of foliage yield in vegetable amaranth (*A tricolor* L.). Indian J. Genet. Plant Breed. 2003; 63(4): 357-358.
17. Kishore N, Dogra RK, Thakur SR, Chahota RK. Stability analysis for seed yield and component traits in amaranthus (*Amaranthus hypochondriacus* L.) in the high altitude dry temperate regions. Indian J. Genet. Plant Breed. 2007;67(2):153-155.
18. Yarnia. Sowing dates and density evaluation of amaranth (cv. Koniz) as a new crop, Advances-in Environmental-Biology Ma'an, Jordan: American Eurasian Net. Sci. In. 2010;4(1):41-46.
19. Khurana DS, Mehta NA, Singh H. Performance of amaranthus genotypes for growth and yield under different nitrogen levels. Indian J. Hortic. 2016;73(1):137-140.
20. Dewan MNN, Haq M E, Hasan MM, Hossain M S, Tareq MZ. Genotype x Environment interaction effects on the field performance of stem amaranth (*Amaranthus tricolor* L.). Bangladesh J. Pl. Breed. Genet. 2017;30(1):21-31.

21. Ejieji CJ, Adeniran KA. Effects of water and fertilizer stress on the yield, fresh and dry matter production of grain Amaranth (*Amaranthus cruentus*). Australian Journal of Agricultural Engineering. 2010;1(1): 18-24.
22. Grafius JE. The Interaction of genotype and night temperature in oat and barley varieties. Agronomy Journal. 1956;48(2): 56-59.
23. De Siqueira Gesteira G, Bruzi AT, Zito, RK, Fronza V, Arantes NE. Selection of early soybean inbred lines using multiple indices. Crop Science. 2018;58(6):2494-2502.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/87049