Original Research Article

ASSESSMENT OF PROMISING DIVERSE GERMPLASM ACCESSIONS FOR STABILITY WITH RESPECT TO YIELD AND ITS ATTRIBUTING TRAITS IN VEGETABLE AMARANTH

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 find 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 (1966) 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 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. These accessions can be selected, commercialised or used in future breeding programs.

Key words: 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 disappeared for centuries and has been rediscovered as a promising crop for its remarkable nutritional value (Wu *et al*., 2000). The *Amaranthus* species are being cultivated for grain as well as leafy-vegetable, some as ornamentals and many are still uncultivated. Vegetable amaranth is a popular leafy vegetable that occupies significant place in India owing to its high nutritive value and fast growing ability with high foliage yield potential within a short duration. The tender leaves and stems are rich in vitamin A and C, calcium and iron. Adequate levels of bioactive components make vegetable amaranthus one of the top five vegetables with enhanced antioxidant levels (Das, 2016). Besides its immense nutritional value, it can be grown in varied environments contributing to climate change mitigation (Jacobsen *et al*., 2015).

Besides yield potential, yield stability over a wide range of agro-climatic conditions is of major concern to the plant breeders for commercial exploitation or effective utilization in breeding programmes. 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. Stability of yield and related traits is greatly affected by the continued variation in climatic conditions. Genotype X Environment interaction forms a significant entity in deciding the worthiness of a crop cultivar (Kang, 2002). Stability analysis helps in the identification of location specific and widely adaptable genotypes (Admassu *et al*., 2008). Identification of promising stable genotypes across agro-ecological niches is of prime concern and yield stability is the ultimate objective in plant breeding. The presence of considerable genetic variability in the amaranth coupled with very high phenotypic plasticity necessitates the evolution of stable genotypes to secure sustainable crop production.

Amaranth crop is more sensitive to environmental variations and the crop yields fluctuate across agro-ecological niches. Hence, the identified promising genotypes of vegetable amaranth need to be evaluated across varied agro-climatic conditions to assess the magnitude of genotype X environment interaction to evolve better and stable varieties for yield and its components, which contributes to the popularization of amaranth as a potential crop with rich nutrition. So, the present investigation was carried out to assess the performance and stability of 30 selected pure breeding lines of vegetable amaranth for yield and yield attributing traits across locations.

2. MATERIALS AND METHODS

Thirty vegetable amaranth accessions selected out of 85 germplasm accessions based on their *per se* performance for fresh green yield and its attributes during summer-18 and *kharif*-18 evaluation were used 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 wre 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 14.00°C to 35.75°C respectively.

The observations on fresh green yield and its attributing traits *viz.,* fresh green yield per hectare, fresh green yield per plant, leaf to stem ratio, plant height, number of leaves per plant, stem diameter, leaf length, leaf width and petiole length were recorded 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 (1966) 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 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), indicated 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 (1966) model to know the extent of linear and nonlinear components of variation which provide information on predictable and unpredictable sources of variation. 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

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. Fresh green yield per hectare recorded across the three environments ranged from 9.28 (IC-551472) to 18.42 tons (VA-16) tons with the mean of 12.37 tons. VA-16 was most promising 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 (1966) an ideally adopted genotype is the one having higher mean value, regression coefficient, bi=1 near unity with least deviation from regression $S^2di=0$. In the

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

Eberhart and Russel model (1966)

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

present study, among the 30 accessions, the genotype VA-16 with a mean yield of 18.42 tons, unit regression co-efficient (bi=1.28) and non-significant deviation of regression co-efficient from zero (S²di= -0.24), was the most promising stable genotype across the locations. In addition, CO-1 with a mean of 16.53 tons (bi=0.63, S²di=-0.56); IC-553719 (mean=14.17 tons, bi=1.38, S²di=1.16) and IC-469645 (mean=13.71 tons, bi=1.63, S²di=-0.07) were considered as high yielding stable genotypes as they have 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 by Shukla and Singh (2003), Shudhir *et al*. (2003), Kishore *et al*. (2007), Dhanapal, (2009), Yarnia (2010) Varalakshmi *et al.* (2011), Khurana *et al.* (2016), and Dewan *et al*. (2017). Superior stable genotypes to all locations as well as specific location are presented in the Table 3.

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

Superior genotypes well adapted to all the environments				
Sl. No.	**Genotypes**	**Grand mean**	**b_i**	**S^2d_i**
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}				

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 (Shukla and Singh, 2003). 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 (Dewan *et al*., 2017).

Performance of genotypes vary according to the changing environments and thus, the relative ranking of genotypes also varies from environment to environment. However some genotypes give consistently better performance across the environments 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 4: Superior genotypes across the different environments 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	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

The overall mean values for significantly interacted yield related 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 (Khurana *et al.,* 2016); 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 (Khurana *et al.,* 2016).

However, many accessions even though had higher mean value with non-significant deviation of regression co-efficient from zero, 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.

On the other hand, 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 adopted to poor environments. Thus, these genotypes are to be tested further in different locations to identify a suitable environment for its adaptability. Similar results were also reported for other accessions by Shukla and Singh (2003); Varalakshmi *et al.* (2011) and Dewan *et al*. (2017), who identified genotypes for adaptability to wide range of climatic conditions and also most promising and stable to low responsive environment. Also by in amaranth.

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**	***S²di***	**Mean**	**bi**	***S²di***	**Mean**	**bi**	***S²di***
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		

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

Some stable accessions identified in the study 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 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 of the accessions as stable for combination of traits *i.e.,* VA-16, CO-1, IC-553719.

Environmental index (Table 7) suggested positive influence at Arabhavi for fresh green yield and its attributing traits compared to low to negative environmental index at Dharwad and Bagalkot. Average yields across the locations indicated that the mean 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 at Dharwad location for fresh green yield, plant height and leaf length. 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.

4. CONCLUSION

In the present study, the accessions VA-16, CO-1, IC-553719 and IC-469645 have been identified as the high yielding stable genotypes. 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. It requires a detailed stability assessment of these genotypes for yield and yield related traits before they are utilized in breeding program or for commercial cultivation.

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

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