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Genetic variations in yield and yield attributing traits of vegetable amaranth (*Amaranthus spp*. L.)

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Abstract
The present investigation was carried out to study different selection parameters for herbage yield and its important yield attributing traits in 52 genotypes of vegetable amaranth (*Amaranthus spp*. L). Genotypic coefficient of variation values ranged from 8.52% (days to 50% flowering) to 66.08% (total herbage yield ha^{-1}) during Kharif 2019-20. The PCV values showed similar trends as GCV and ranged from 8.74% (days to 50% flowering) to 67.46% (total herbage yield ha^{-1}). The values of heritability estimates were high for all the traits and ranged from 78.10% (leaf: stem ratio) to 95.95% (total herbage yield ha^{-1}). The expected genetic advance as percent of mean varied from 16.16% (Days to first harvest) to 133.35% (Total herbage yield ha^{-1}). High genetic advance as percentage of mean (GAM) which coincide with high heritability were observed for total herbage yield ha^{-1}, leaf area, fresh leaf weight plant^{-1}, fresh stem weight plant^{-1}, fresh green yield plant^{-1}, plant height, stem diameter, leaf width, leaf length, petiole length and number of leaves plant^{-1}. These characters may be used as early indicators in selection programmers of vegetable amaranth. Based on the performance, promising genotypes Arka Suguna, CO-1, KVA-18, Nisco Red, KVA-34, Pusa Kiran, KVA-28, KVA-32, Pusa Lal Chauli and KVA-1 have been found superior among the genotypes which can be used in breeding programmers for crop improvement

Keywords: Vegetable amaranth, herbage yield, genetic variability, heritability and genetic advance

Introduction
Amaranthus (*Amaranthus* spp.) is one of the most popular leafy vegetable commonly known as Chauli (in Hindi), Dantina soppu or Rajgiri soppu (in Kannada) and belongs to the family Amaranthaceous. Amaranths (*Amaranthus* sp.) consist of a group of versatile food crops exhibiting high adaptability to new environments, even in the presence of different biotic and abiotic stresses (Rana *et al*., 2007) [21]. They can be grown under varying soil and agro-climatic conditions all year round but summer and rainy are main growing seasons. Unlike other leafy vegetables, it is grown during hot summer months when no other green vegetables are available in the market (Singh and Whitehead, 1996) [2]. Amaranth leaves are a rich and cheaper source of dietary fibre, proteins, vitamins and a wide range of minerals (Prakash and Pal, 1991; Shukla *et al*., 2003; Routray *et al*., 2012; Venskutonis & Kraujalis; 2013) [20, 30, 25,38]. They serve as an alternative source of nutrition for vegetarian people in developing countries where the bulk of the population has little access to protein-rich food.

Amaranths are dicotyledonous herbaceous plants including approximately 70 species, of which seventeen produces edible leaves and three produces food grains (Jansen, 2004) [11]. The vegetable amaranth is a popular leafy vegetable in the South- East Asia and is becoming increasingly popular in the rest of the continent due to its attractive leaf color, taste and nutritional value. The genus has been reported to have anticancer properties (Dusgupta & De, 2007) [10]. A wide variation is reported to exist within each species for growth habit, disease resistant, taste and quality, thus offering considerable scope for future breeding program.

Presence of variability in a base population is very important for any improvement program. Identification of genotypes with various genetic parameters like coefficient of variation, heritability and genetic advance provide a clear insight into the extent of variability and a relative measure of the efficiency of selection of genotypes based on phenotype, in a highly variable population (Venkatesh *et al*., 2014) [37]. Genetic advance can be used to predict the efficiency of selection (Showemimo *et al*., 2021) [31]. In this light, a preliminary field experiment was conducted to reveal the nature and extent of genetic variation among 52 genotypes of vegetable amaranthus at Kittur Rani Chanamma College of Horticulture, Arabhavi, Belagavi and Karnataka, India.

Materials and Methods

The study was carried out between August to October 2019 (Kharif 2019-20) as a preliminary experiment for characterization of 52 genotypes including checks at the Department of Vegetable Science, Kittur Rani Chanamma College of Horticulture, Arabhavi, Belagavi District, Northern Dry Zone Karnataka, India. The experimental plot was laid out in RCBD design with two replications. The crop was raised as per the package of practices of University of Horticultural Sciences, Bagalkot (Anon, 2015) [2]. The experimental plot was ploughed repeatedly and land was brought to fine tilt. The plot size of each treatment was 1.8 × 1.2m^2 with row to row and plant to plant distance of 30cm and 15cm respectively. Prior to sowing 10tons/ha of FYM was added in experimental field to enhance the water holding capacity of the soil. Throughout the crop season, weeding followed by hoeing was done at the interval of 10 days. Since, the crop was grown during Kharif (day temp. ranges from 18-30◦C), as rainfed crop, irrigation was advised depending upon the rainfall at interval of 4-5 days during the initial crop growth and continued throughout the crop season. The data were recorded on 5 randomly selected plants in each replication for fresh green yield (g per plant) and its twelve contributing morphological traits. The raw data was compiled by taking the means of all the plants for each treatment and replication for different traits during the experiment. The means of Kharif 2019-20 season was subjected to further statistical analysis of the data was carried out using Intestate programmer at the Department of Crop improvement and Biotechnology at College of Horticulture, Bengaluru the following statistical methods were employed for analysis of data. Analysis of variance was done according to Panse & Sukhatme (1985) [19] for each character. The phenotypic (PCV) and genotypic coefficient of variation (GCV), heritability in broad sense (h^2B) were estimated according to Burton and Devane (1953) [5], expected genetic advance over mean (GAM) were estimated according to Johnson *et al.* (1955) [12].

Results and Discussion

Analysis of variance

The analysis of variance for herbage yield and its attributing traits revealed highly significant differences for all the characters studied under Kharif 2019-20 season (Table 3). This is an indication for existence of the considerable amount of variability in the material studied under the present experiment.

The mean performance of 52 genotypes for herbage yield and its twelve contributing morphological characters are presented in Table 2 and 3 respectively. The genotype KVA-11 (24.63g) exhibited maximum fresh green yield plant^{-1} followed by KVA-28, CO-1, KVA-9 and KVA-18. The genotypes KVA-23 and KVA-2 showed poor fresh green yield. Variation among amaranth genotypes has also been documented for green yield by Varalakshmi and Pratap (1994) [36]; Ahammed *et al.* (2012) [1], Mandal *et al.* (2013) [16] and Sarker *et al.* (2018) [27].

Table 1: Analysis of variance for growth, earliness and yield parameters of vegetable amaranthus genotypes during Kharif 2019-20

Sl. No.	Source of variation / Characters	Replication	Treatments (Genotypes)	Error	S.Em±	CD (5%)
	Degrees of freedom	1	51	51		
A. Growth parameters						
1.	Plant height (cm)	8.683	40.059**	2.201	1.039	2.979
2.	Stem diameter (mm)	0.634	2.947**	0.253	0.352	1.011
3.	Number of leaves per plant	1.789	4.487**	0.460	0.475	1.362
4.	Leaf length (cm)	1.931	4.688**	0.583	0.535	1.533
5.	Leaf width (cm)	0.017	2.222**	0.182	0.299	0.858
6.	Leaf area (cm^2)	43.318	195.766**	11.743	2.400	6.879
7.	Petiole length (cm)	0.477	1.344**	0.123	0.245	0.705
B. Earliness parameters						
8.	Days to first harvest.	3.846	20.655**	3.297	1.272	3.645
9.	Days to 50% flowering	0.471	57.832**	2.824	1.177	3.374
C. Yield parameters						
10.	Fresh leaf weight per plant (g)	1.988	9.650**	0.857	0.648	1.858
11.	Fresh stem weight per plant (g)	0.062	8.169**	1.304	0.800	2.292
12.	Leaf: Stem ratio (L:S ratio)	0.139	0.264**	0.058	0.168	0.482
13.	Fresh green yield per plant (g)	4.252	27.618**	4.032	1.406	4.031
14.	Total herbage yield per ha (ton)	0.053	53.744**	2.176	1.033	2.962

** Significant at 1%, * Significant at 5%, NS: Non significant

A perusal of Table 2 showed that the mean values of a number of genotypes for each of the character was high over their corresponding arithmetic means. For example, the genotypes, KVA-1, KVA-7, KVA-11, KVA-15, KVA-18, Nisco Red, KVA-28, KVA-31, KVA-32, KVA-34, Renushree, Arka Suguna, Pusa Kiran, Pusa Lal Chauli and CO-1 had high mean values than arithmetic mean (7.68 ± 1.04) for total herbage yield. Similarly, the genotypes Arun and Konkan Durangi had highest plant height; KVA-18 showed maximum stem diameter; KVA-5 had more number of leaves plant^{-1} followed by KVA-11, KVA-7, KVA-10, Nisco Red, KVA-4; genotype CO-1 having higher petiole length. These findings are in close proximity with the results of Varalakshmi (2004) [35], Shukla *et al.* (2006) [29], Diwan *et al.* (2017) [9], Tejaswini *et al.* (2017) [33], Sarker *et al.* (2018) [27], and Rashad and Sarkar (2020) [23].

Genotype KVA-29 took maximum number of days for flowering (74.50) followed by KVA-24, Rajgiri Red, KVA-21 and KVA-33 indicates late flowering behavior, whereas Arka Varna took least number of days (50.50) followed by Arka Samraksha, Pusa Lal Chauli, KVA-18 and KVA-9 as early flowering genotypes. Genotype KVA-28 (multicity type) had recorded maximum leaf length (12.19cm), leaf width (8.16cm), leaf area (64.63cm^2) and fresh leaf weight plant^{-1}

(11.55g). Similarly, maximum fresh stem weight plant^{-1} (Table 3) was noticed in KVA-11 (11.66g); genotype KVA-5 exhibited higher leaf: stem ratio (1.83) followed by KVA-7, Arun, CO-1, Nisco Red, Arka Suguna and KVA-34. In the same way, high range of variation for leaf and stem fresh weight was also reported by Campbell and Abbott (1982) [6] and Rani and Veeraragavathatham (2003) [22]; Kumar (2015) [14]; Diwan *et al*. (2017) [9]; Sarker *et al*. (2018) [27] for leaf: stem ratio. Mandal *et al*., (2013) [16], Chattopadhyay *et al*. (2013) [7], Diwan *et al*. (2017) [9], Tejaswini *et al*. (2017) [33] and Rashad and Sarkar (2020) [23] who expressed similar views on the edible part partitioned into leaf and stem components, which helps to understand the relative contribution of different plant parts (*i.e.* leaf and stem) towards yield. Leaf: stem ratio is also a good indicator of leafiness of a genotype. High leaf and stem ratio indicated that the leaf portion contributed to the yield more than the stem portion. Genotypes having high mean values for various traits may serve as promising material for selection of plant type with increase yield potential as well as for other yield contributing traits for which they showed high mean performance. Genotypes showing high mean performance for specific traits can be used as donor parent for improving those traits in component breeding.

High leaf and stem ratio indicated that the leaf portion contributed to the yield more than the stem portion. Genotypes having high mean values for various traits may serve as promising material for selection of plant type with increase yield potential as well as for other yield contributing traits for which they showed high mean performance. Genotypes showing

Table 2: Mean, coefficient of variation (CV) and Critical difference (CD) values for different morphological and earliness traits in vegetable amaranthus (Kharif-2019-20)

Sl. No.	Genotypes	PH (cm)	SD (mm)	NL	LL (cm)	LW (cm)	LA (cm^2)	PL (cm)	DFH	DFF
1	KVA-1	23.29	7.20	9.20	7.84	4.50	22.97	4.18	32.00	63.00
2	KVA-2	16.66	7.13	7.30	6.38	4.34	17.97	3.44	32.50	60.00
3	KVA-3	20.64	4.76	9.80	6.56	5.24	22.09	4.40	27.00	61.50
4	KVA-4	19.92	3.88	10.90	5.11	4.46	14.90	4.03	34.00	64.00
5	KVA-5	19.22	4.54	12.10	9.70	6.68	42.09	3.86	32.50	57.00
6	KVA-6	18.72	3.86	10.70	8.77	5.23	29.74	4.00	29.50	62.00
7	KVA-7	19.57	6.23	11.60	9.40	5.73	35.00	4.58	31.00	61.00
8	KVA-8	19.33	5.15	7.00	6.98	4.31	19.82	3.87	32.00	62.50
9	KVA-9	19.43	5.38	8.60	7.20	4.22	19.81	4.12	37.50	55.50
10	KVA-10	23.03	5.73	11.50	7.93	5.74	29.63	4.71	34.50	63.50
11	KVA-11	19.66	5.28	11.60	8.90	6.15	35.57	4.98	29.00	57.50
12	KVA-12	30.31	6.91	8.30	6.81	3.80	16.79	2.92	43.00	56.00
13	KVA-13	19.75	5.89	7.10	6.85	4.54	20.15	3.91	37.00	56.50
14	KVA-14	18.81	6.90	7.60	5.92	5.01	19.26	3.33	36.00	59.00
15	KVA-15	19.08	6.86	7.90	7.28	5.25	24.91	4.92	31.00	56.50
16	KVA-16-1	18.55	5.98	7.30	7.55	4.61	22.55	4.46	32.50	68.00
17	KVA-16-2	17.13	6.82	8.90	8.98	7.23	42.13	4.62	36.50	56.50
18	Nisco Red	28.47	6.74	11.10	8.12	6.08	32.04	4.68	36.00	57.50
19	KVA-17	18.23	3.62	7.50	7.53	6.41	31.35	4.84	33.00	59.00
20	KVA-18	29.15	8.76	6.80	7.61	5.74	28.20	5.15	32.00	55.50
21	KVA-19-1	18.66	4.40	7.30	8.95	5.79	33.81	4.73	37.00	66.50
22	KVA-19-2	20.12	4.92	6.90	7.91	7.70	39.66	3.77	34.00	57.50
23	KVA-20	19.97	7.08	6.90	7.40	3.51	16.95	5.82	27.00	65.00
24	KVA-21	20.77	5.91	9.80	10.06	6.07	39.75	4.49	34.00	70.50
25	KVA-22	18.04	4.74	9.50	10.32	5.89	39.61	5.21	37.50	68.50
26	KVA-23	20.64	3.24	8.90	7.92	4.84	24.95	3.97	31.50	56.00
27	KVA-24	19.65	4.92	7.60	11.61	5.45	41.09	4.22	34.00	72.00
28	KVA-25	17.46	6.82	6.60	6.54	4.15	17.58	3.94	39.50	58.50
29	KVA-26	19.86	7.14	6.70	5.70	4.42	16.41	4.73	35.00	57.50
30	KVA-27	19.00	5.30	7.90	6.49	7.33	30.85	4.14	31.50	65.50
31	KVA-28	18.58	4.57	8.80	12.19	8.16	64.63	5.30	33.50	68.00
32	KVA-29	18.64	3.87	6.90	8.08	5.28	27.67	5.62	37.00	74.50
33	KVA-30	30.97	7.60	9.20	8.52	6.94	38.43	5.21	34.00	65.50
34	KVA-31	25.68	6.22	8.00	7.11	3.94	18.39	3.22	36.00	68.00

Table 2: Contd...

Sl. No.	Genotypes	PH (cm)	SD (mm)	NL	LL (cm)	LW (cm)	LA (cm^2)	PL (cm)	DFH	DFF
35	KVA-32	30.24	7.31	7.20	6.34	5.11	21.00	4.99	35.00	65.50
36	KVA-33	21.59	7.11	8.40	5.86	5.24	19.80	3.52	36.00	69.00
37	KVA-34	24.60	6.63	7.10	8.12	5.59	29.58	3.52	37.50	61.00
38	Suchino Red	31.11	6.38	8.40	5.49	3.79	13.52	1.88	39.50	56.50
39	AAS-1	24.35	6.74	7.90	6.11	5.14	20.24	2.92	37.00	68.50
40	AAS-2	21.51	6.02	8.00	6.18	5.42	21.76	3.98	34.00	66.50
41	AAS-3	18.84	5.56	7.00	5.62	4.16	15.25	3.12	36.50	57.00
42	ASS-1	18.24	6.66	8.30	5.57	4.02	14.23	3.87	38.50	58.00

43	Rajgiri Red	22.24	7.06	9.70	7.45	5.78	27.98	4.42	39.50	71.00
44	Arun	32.56	7.37	10.10	7.30	5.61	26.57	3.63	37.00	62.00
45	Renushree	28.88	6.93	8.50	8.06	5.49	28.78	5.41	34.00	58.50
46	Arka Samaraksha	24.55	6.77	7.10	6.48	4.77	20.02	3.93	33.00	54.00
47	Arka Varna	17.04	6.11	8.10	6.16	4.90	19.60	4.55	30.00	50.50
48	Pusa Kiran	25.88	6.24	8.20	6.03	3.93	15.46	3.53	37.00	57.50
49	Pusa Lal Chauli	25.22	4.51	7.70	5.92	4.55	14.23	4.10	34.50	55.50
50	Konkan Durangi	32.26	7.38	10.00	9.16	4.37	25.66	5.67	31.00	60.50
51	Arka Suguna	23.77	5.07	6.80	7.06	5.93	27.19	3.90	35.50	63.00
52	CO-1	22.07	6.01	9.90	7.97	6.22	32.25	6.05	34.50	59.50
	Mean	22.15	5.96	8.50	7.52	5.28	26.34	4.27	34.42	61.53
	S.Em±	1.05	0.36	0.48	0.54	0.30	2.42	0.25	1.28	1.19
	CV (%)	6.70	8.44	7.98	10.16	8.09	13.01	8.21	5.28	2.73
	C.D. at 5%	2.98	1.01	1.36	1.53	0.86	6.88	0.70	3.65	3.37

PH Plant height (cm)
SD Stem diameter (mm)
NL Number of leaves per plant
LL Leaf length (cm)
LW Leaf width (cm)
LA Leaf area (cm^2)
PL Petiole length (cm)
DFH Days to harvest
DFF Days to 50% flowering

Table 3: Mean, coefficient of variation (CV) and Critical difference (CD) values for yield parameters in vegetable amaranthus (Kharif 2019-20)

Sl. No.	Genotypes	L:S ratio	FLW (g/plant)	FSW (g/plant)	FGY (g/plant)	THY (t/ha)
1	KVA-1	0.75	5.13	6.94	13.61	11.41
2	KVA-2	0.78	2.45	3.16	8.34	4.00
3	KVA-3	1.15	7.93	7.01	16.87	6.99
4	KVA-4	0.92	5.54	6.17	10.91	5.91
5	KVA-5	1.83	8.73	4.79	12.80	3.90
6	KVA-6	0.96	5.95	6.17	11.33	3.94
7	KVA-7	1.82	7.58	4.16	14.07	14.18
8	KVA-8	0.64	3.05	4.69	10.43	4.32
9	KVA-9	0.52	5.74	11.12	18.75	9.56
10	KVA-10	0.84	7.69	9.16	17.17	4.21
11	KVA-11	0.92	10.66	11.66	24.63	13.91
12	KVA-12	1.21	5.76	5.02	13.16	3.93
13	KVA-13	0.85	4.00	4.79	12.17	4.31
14	KVA-14	0.96	3.83	4.02	11.03	2.43
15	KVA-15	0.88	5.47	6.31	11.23	10.43
16	KVA-16-1	0.78	3.66	4.75	10.13	4.11
17	KVA-16-2	0.75	3.59	4.81	11.14	7.66
18	Nisco Red	1.71	6.01	3.99	12.66	14.69
19	KVA-17	1.29	5.70	4.58	12.90	5.21
20	KVA-18	0.80	7.63	9.61	18.64	20.20
21	KVA-19-1	1.64	8.27	5.15	15.43	5.27
22	KVA-19-2	1.21	6.59	5.48	15.24	3.19
23	KVA-20	0.65	2.89	4.55	8.78	5.34
24	KVA-21	1.71	7.88	4.62	17.76	4.74
25	KVA-22	0.48	2.52	5.24	11.60	2.95
26	KVA-23	0.94	7.36	7.89	7.18	3.53
27	KVA-24	1.20	9.18	7.66	18.30	5.79
28	KVA-25	0.89	5.05	5.68	13.31	2.95
29	KVA-26	0.72	3.56	5.00	10.80	3.71
30	KVA-27	0.71	3.74	5.32	12.29	2.82
31	KVA-28	1.06	11.55	10.90	24.03	16.71
32	KVA-29	0.88	7.17	8.17	16.41	4.71
33	KVA-30	0.97	4.08	4.18	9.63	4.86
34	KVA-31	0.95	2.84	3.17	8.58	10.91
35	KVA-32	0.98	6.95	7.31	16.28	13.14
36	KVA-33	0.77	6.09	7.99	16.76	4.54
37	KVA-34	1.37	4.80	3.96	11.79	18.55
38	Suchino Red	0.70	4.19	5.97	12.71	3.36
39	AAS-1	0.60	5.31	9.26	16.72	6.60
40	AAS-2	1.42	7.54	5.37	15.80	5.25
41	AAS-3	1.05	6.63	6.36	16.05	2.45

42	ASS-1	0.80	4.08	5.19	11.28	3.07
43	Rajgiri Red	1.22	5.83	4.79	13.31	6.00
44	Arun	1.80	7.38	4.11	13.70	7.97
45	Renushree	1.16	6.94	6.04	15.84	13.92
46	Arka Samraksha	0.85	4.69	5.65	13.33	5.79
47	Arka Varna	0.78	4.10	5.81	12.41	5.85
48	Pusa Kiran	0.78	2.80	3.60	9.31	12.38
49	Psa Lal Chauli	0.73	3.10	4.25	10.44	10.57
50	Konkan Durangi	0.79	5.73	7.25	15.59	5.75
51	Arka Suguna	1.58	6.17	3.96	14.02	19.98
52	CO-1	1.72	10.93	6.44	21.16	21.74
	Mean	1.03	5.81	5.94	13.80	7.68
	S.Em±	0.17	0.65	0.81	1.42	1.04
	CV (%)	23.44	15.94	19.21	14.55	19.20
	C.D. at 5%	0.48	1.86	2.29	4.03	2.96

L:S ratio Leaf: Stem ratio
FLW /plant Fresh leaf weight (g/plant)
FSW/ plant Fresh stem weight (g/plant)
FGY /plant Fresh green yield (g/plant)
THY/ ha Total herbage yield (t/ha)

High mean performance for specific traits can be used as donor parent for improving those traits in component breeding.

Genotypes KVA-3 and KVA-20 took least number of days (27.00) to first harvest followed by KVA-11, KVA-6 and Arka Varna (Table 2). Generally vegetable amaranthus is harvested at 20 to 30 days after sowing to consume as tender greens. Consumption of plants within 15 to 20 days as well as at the mature stages of 35 to 40 days after sowing is also not uncommon during irrespective of seasons. Kader (1978) [13] reported that the optimum stage of harvest in amaranthus could be fixed at 25th day after sowing, as at this stage the performance was found to be superior with enhanced leaf weight, stem weight, leaf length, leaf breadth, stem diameter and plant height; According to Vijayakumar (1980) [39], the optimum stage of harvest in most of the types of amaranthus could be fixed between 25-30 days after sowing to get the highest yield as well as nutritious and palatable greens.

The mean, range, estimates of variance components ($\sigma2g$, $\sigma2p$ and $\sigma2e$), genotypic (GCV) and phenotypic (PCV) coefficient of variation, broad sense heritability and genetic advance are given in Table 4. The relative amount of genetic variation is best expressed as genotypic coefficient of variation (GCV), since this variable takes into account the mean value as well as the unit of measurement into consideration. Genotypic coefficient of variation values ranged from 8.52% (days to 50% flowering) to 66.08% (total herbage yield ha^{-1}) for Kharif 2019-20. The PCV values showed similar trends as GCV and ranged from 8.74% (days to 50% flowering) to 67.46% (total herbage yield ha^{-1}). The values of PCV were higher than the corresponding GCV values for all the characters though the differences were low. Higher estimates of phenotypic and genotypic coefficients of variation were observed for total herbage yield ha^{-1} (Ahammed *et al*., 2012 [1]; Dhangrah *et al*., 2015) [8], leaf area (Revanappa *et al*., 1998 [24]; Rashad and Sarker 2020 [23]; Oduwaye *et al*., 2017) [17], fresh leaf weight plant^{-1}, leaf: stem ratio, fresh green yield plant^{-1} (Sarker *et al*., 2018 [27]; Panda *et al*., 2017) [18] and fresh stem weight plant^{-1} [Revanappa *et al*. (1998) [24], Dhangrah *et al*. (2015) [8], Oduwaye *et al*. (2017) [17] and Panda *et al*. (2017) [18].

In the same way, moderate magnitude of phenotypic and genotypic coefficients of variance with closer values were recorded in kharif 2019-20 for leaf width (Oduwaye *et al*., 2017) [17], petiole length (Diwan *et al*. 2017 [9]; Panda *et al*., 2017 [18]; Oduwaye *et al*., 2017 [17]) and number of leaves (Rashad and Sarker, 2020 [23]; Panda *et al*., 2017) [18] respectively. While, moderate magnitude of GCV with higher PCV for plant height (Oduwaye *et al*., 2017) [17], stem diameter and leaf length (Mandal *et al*., 2010 [16]; Diwan *et al*. 2017) [9] respectively were recorded in the kharif 2019-20. The small differences between PCV and GCV for all the traits indicated that the variability was primarily due to genotypic differences *i.e.* less environmental influences. Similar, results on amaranthus were also reported by Shukla *et al*. (2006) [29] and Buhroy *et al*. (2017) [4].

Traits like Days to first harvest and days to 50% flowering had lower magnitude of GCV and PCV, which implies that chances of getting substantial gains under selection are likely to be less for these characters. Similar, result was also reported by Dhangrah *et al*., 2015 [9]. On the other hand high values of coefficient of variation for leaf area, fresh leaf weight plant^{-1}, leaf: stem ratio, fresh stem weight plant^{-1} and fresh green yield plant^{-1} indicated considerable scope for improvement in these traits through selection to enhance the potentiality of herbage yield. The significant genetic variability in any breeding material is a prerequisite as it does not only provide a basis for selection but also provide some valuable information regarding selection of diverse parents for use in hybridization programmer (Singh *et al*., 2016 [32]; Upadhyay *et al*., 2019) [34].

High heritability alone is not enough to make sufficient improvement through selection generally in advance generations unless accompanied by substantial amount of genetic advance (Bhargava *et al*., 2004) [3]. The utility of heritability is therefore increased when they are used to calculate genetic advance, which indicates the degree of gain in a character obtained under a particular selection pressure. Thus, genetic advance is yet another important selection parameter that aids breeder in a selection programmer (Shukla *et al*., 2004) [28]. It has been emphasized that without genetic advance, the heritability values would not be of practical importance in selection based on phenotypic appearance. So, the genetic advance should be considered along with heritability in coherent selection breeding programmers (Johnson *et al*., 1955) [12]. In our study, the magnitude of genotypic and phenotypic variances were quite comparable *i.e.* due to lesser role of environmental effect ($\sigma 2g + \sigma 2e = \sigma 2p$) thus all the traits were under the control of genotypic variance (additive+non-additive). However, in general, it is considered that if a character is governed by non-additive gene action, it may give high heritability but low genetic advance, whereas if the character is governed by additive gene action, heritability and genetic advance both would be high. Since, in the present study expected genetic advance values were based on broad sense heritability, which incorporate both additive and non-additive components of gene actions, much reliance cannot be placed on expected genetic advance. But, the traits, which had high heritability and also showed high expected genetic advance, could be substantially considered for making selections as these traits were mainly influenced by the major effects of additive gene action.

Table 4: Estimates of genetic variability parameters for yield and yield attributing traits during Kharif (2019-20) season

Sl. No	Characters	Mean ± S.Em	Range	GCV (%)	PCV (%)	h^2 (broad Sense)	GAM
Growth parameters							
1.	Plant height (cm)	22.15 ± 1.04	16.66 -32.56	19.64	20.20	94.50	39.33
2.	Stem diameter (mm)	5.96 ± 0.35	3.24 - 8.76	19.46	20.36	91.40	38.33
3.	Number of leaves per plant	8.50 ± 0.48	6.60 - 12.10	16.69	17.61	89.74	32.56
4.	Leaf length (cm)	7.52 ± 0.53	5.11- 12.19	19.05	20.36	88.73	36.73
5.	Leaf width (cm)	5.28 ± 0.30	3.51 - 8.16	19.12	19.96	91.79	37.74
6.	Leaf area (cm^2)	26.34 ± 2.40	13.52 - 64.63	36.41	37.55	94.00	72.73
7.	Petiole length (cm)	4.27 ± 0.25	1.88 - 6.05	18.28	19.18	90.84	35.90
Earliness parameters							
8.	Days to first harvest	34.42 ± 1.27	27.00 - 43.00	8.56	9.34	84.04	16.16
9.	Days to 50% flowering	61.53 ± 1.18	50.50 - 74.50	8.52	8.74	95.12	17.12
Yield parameters							
10.	Fresh leaf weight per plant (g)	5.81 ± 0.65	2.45 - 11.55	36.11	37.83	91.12	71.02
11.	Fresh stem weight per plant (g)	5.94 ± 0.80	3.16 - 11.66	31.17	34.00	84.04	58.86
12.	Leaf: Stem ratio (L:S ratio)	1.03 ± 0.17	0.48 - 1.83	31.29	35.41	78.10	56.97
13.	Fresh green yield per plant (g)	13.80 ± 1.41	7.18 - 24.63	24.88	26.92	85.40	47.37
14.	Total herbage yield per ha (ton)	7.68 ± 1.03	2.43 - 21.74	66.08	67.46	95.95	133.35

Highest expected genetic advance was noticed for total herbage yield (133.35%) followed by leaf area (72.73%), fresh leaf weight $plant^{-1}$ (71.02%), fresh stem weight $plant^{-1}$ (58.86%), fresh green yield $plant^{-1}$, plant height, stem diameter (Sarker *et al*., 2016 [26]; Venkatesh *et al*., 2014) [37] leaf width, leaf length, petiole length and number of leaves $plant^{-1}$ (Sarker *et al*., 2016 [26]; Venkatesh *et al*., 2014 [37]; Dhangrah *et al*., 2015 [8]; Panda *et al*., 2017 [18]; Ahammed *et al*., 2012 [1]; Rashad and Sarker, 2020) [23] in kharif 2019-20. Whereas, leaf: stem ratio exhibited moderate heritability with high genetic advance as percent of mean (Ahammed *et al*., 2012) [1]. These traits also showed moderate to high coefficient of variation and high heritability values, which indicated a major role of additive gene action in the inheritance of these characters and their amenability for improvement in the population for herbage yield and its component traits.

Conclusion

The analysis of variance of all character studied was significant that revealed wide range of variability among the 52 genotypes of vegetable amaranth. Considering mean, range and all genetic parameters, selection could be performed on the basis of leaf area, fresh leaf weight per plant, fresh stem weight per plant and leaf: stem ratio for the improvement of herbage yield of vegetable amaranth. Based on mean performance the genotypes *viz*., Arka Suguna, KVA-18, KVA-28, KVA-34, Nisco Red, Pusa Kiran, Pusa Lal Chauli, KVA-32 along with CO-1 as check variety had higher herbage yield and its attributing traits. Further, these genotypes could be used as parent materials for future breeding programs.

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