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Morphological, physiological and bio-chemical characterization of amaranth (*Amaranthus* spp.) genotypes

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Abstract

The Present investigation was carried out with 12 amaranth genotypes including two check variety (Pusa Kirti and Pusa Kiran) during Rabi 2022-2023 in RBD with three replications at Field Experimentation Centre, Department of Genetic and Plant Breeding, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, (U.P.), to evaluate Amaranth (*Amaranthus* spp.) genotypes for Morphological, Physiological and Bio-Chemical parameters. Analysis of variance showed highly significant differences among 12 Amaranth genotypes for 13 Morphological, 2 Physiological and 2 Bio-Chemical characteristics. Genotype IC-35578 was identified as the best genotype for 7 Morphological and 2 Physiological characters, and genotype IC-35583 was identified as the best genotype for 9 Morphological and 2 Bio-Chemical characters.

Keywords: Bio-chemical, genotype, morphological, physiological, RBD.

Introduction

Amaranth belongs to the Amaranthaceae family and encompasses a wide range of species, some of which are cultivated for their edible leaves, seeds, and even decorative purposes. The word Amaranth is derived from Greek phrase "ama' rantos" which means "unfading flower". Amaranth (*Amaranthus* spp. L.) is one of the important and popular vegetables of India. Amaranth (*Amaranthus* spp. L.), belongs to the family Amaranthaceae, grown during summer and rainy seasons in India. It is also known as pig weed, Chinese spinach and Tampala. It is native to the India or Indo-Chinese region (Islam and Hossain, 1992). The genus Amaranth includes 50-60 species, cultivated for leaf as well as for grains and few are wild species. The vegetable amaranth species (2n = 34) includes *A. tricolor, A. dubius, A. lividus, A. blitum, A. hypochondiacus, A. spinosus*, and *A. viridis*, while (2n = 32) includes *A. cruentus* and *A. tristis*, *A. graecizans* and *A. caudatus*. Centres of diversity for amaranth are Central and South America, India and South East Asia with secondary centres of diversity in West and East Africa. Main vegetable type of leaf amaranth is *Amaranthustri color* L., originated in south East Asia, particularly in India (Rai and Yadav, 2005). Amaranth is cultivated all over the country in any season due to its adaptability to wide range of soil and climate. However, during winter its growth and development is slower than summer

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and rainy season (Islam and Hossain, 1992). Among the vegetables of tropics, amaranth is very easy to grow for its early growing habits and rich in minerals and vitamin (Shanmugavelu, 1989). According to Kelly and Martin (1983), the leaves and stem of amaranth are good source of iron (3.9mg/100 mg), calcium (267 mg), vitamin-A (6100 IU), vitamin-C (80 mg), protein (3.5 g), carbohydrate (6.5 g), fat (05 g) and moisture (86.9%) (Bose *et al.,* 1993 and Kachiguma *et al.,* 2015). Amaranth has high amount of essential amino acids as whole egg protein (Drzewiecki *et al.,* 2003). Amaranth demonstrates genetic diversity and remarkable phenotypic plasticity, enabling it to adapt and thrive in adverse growing conditions like drought resistance. It exhibits resilience to extreme temperatures, drought, and poor soil conditions, making it suitable for regions that face such challenges. Amaranths have high capacity of osmotic adjustment and is a C4 plant tolerant to drought, and plant diseases and a suitable option for climate change (Ruth *et al.,* 2021). A major advantage of amaranth is also its ability to reclaim and flourish on agriculturally marginal lands. It has great potential for establishing themselves on marginal and wasteland across the tropics (Hegde, 2002). Amaranth's ability to grow effectively in such environments makes it a valuable option for farmers. As stated by (Tejaswini *et al.,* 2017), Amaranth has gained recognition as a promising agricultural crop over the past two decades due to its remarkable ability to endure high temperatures, periods of drought, diseases, and pests. Additionally, the seeds of this crop possess exceptional nutritional value. Notably, (Sarker *et al.,* 2014) demonstrated that Amaranth offers a flavour comparable to, if not superior than, that of spinach. Furthermore, this crop boasts significantly higher levels of protein (14-30% when considering dry weight), essential minerals such as iron, manganese, and zinc (Alvarez *et al.,* 2010), as well as antioxidants like beta carotenoids (ranging from 90 to 200 mg/kg) and ascorbic acid (approximately 28 mg per 100g) in comparison to other leafy vegetables (Becker, 1981).

Materials and Methods

The present study was conducted during the rabi season 2022 at the field experimentation center, Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.). Experiment was laid out in randomized block design with 12 genotypes *viz.* IC 35574 (G51), IC 35575 (G52), IC 35576 (G53), IC 35577 (G54), IC 35578 (G55), IC 35579 (G56), IC 35580 (G57), IC 35581 (G58), IC 35582 (G59), IC 35583 (G60), Pusa Kirti (C1) and Pusa Kiran (C2). The genotypes were sown on 5 Dec 2022 and harvested on 3rd week of April at the Shuats college Research Station. The seedlings were sown at 30×30 cm^2 spacing. The crop was applied with 40 Kg N and 20 Kg P_2O_5 per hectare. The nitrogen was applied in two splits, one at the time of transplanting and other at 25 days after transplanting. Entire Phosphorus was applied as basal dose. Line sowing method was followed for seed sowing, in which each genotype was sown in 2 lines. The length of the line was 3m, in which 2 seeds were sown at a place. Plant to Plant Distance was 30 cm, Row to Row distance was 30 cm between seeds of same genotype and 40 cm between different genotypes. The response of crop for different seed treatments were interpreted in terms of Plant Height (15, 30, 45, 60 DAS), Number of Branches per plant, Number of leaves per plant, Length of leaves (cm), Leaf area, Leaf colour, Leaf shape, Diameter of stem, Days to Flowering, Length of inflorescence, Days to maturity of seed, Days to first harvest, Number of harvesting, Yield per plot (gm), Yield per hectare (t), Biological Yield, Harvest Index (%), Test weight of seeds, Fiber Content (%), Oil content (%) and the Pearson correlation.The mean sum of squares value for above characters were subjected to analysis of variance for experimental design.

Results and Discussion

Days to 50% flowering

The genotype G60 (IC – 35583) was recorded as the 1st genotype to reach 50% flowering stage, at 48.80 days after sowing followed by G57 with 50.43 days to reach 50 % flowering stage and G55 (IC – 35578) was the last genotype to reach 50% flowering stage at 65.50 days after sowing (Table 1). These findings are supported by Srivastava *et al.* (2020) and Paliwal *et al.* (2022).

Plant height (cm)

The genotype G55 (IC – 35578) was longest in plant height (119.87 cm), followed by Pusa Kiran (115.11 cm) and genotype G53 (IC-35576) was lowest 76.77 cm (Table 1). These findings are supported by Ahammed *et al.* (2012) and Jangir *et al.* (2019).

Inflorescence length (cm)

The genotype G60 (IC-35583) was longest in Inflorescence length (49.57 cm), followed by G57 (IC-35580) with 41.04 cm and genotype Pusa Kirti was lowest 11.66 cm (Table 1). These findings are supported by Kumar and Yassin (2014) and Dinssa *et al.* (2018).

Stem diameter (cm)

The genotype G60 (IC-35583) was thickest in stem diameter 0.94 cm, followed by G56 (IC-35579) with 1.18 cm and genotype Pusa Kirti was lowest with 0.55 cm (Table 1). These findings are supported by Bhalekar *et al.* (2019) and Jangir *et al.* (2019).

Number of branches per plant

The genotype G60 (IC-35583) was (27.39) having highest number of branches, followed by G59 (IC-35582) with 26.18 branches and genotype Pusa Kirti was lowest with 9.46 branches (Table 1). These findings are supported by Dinssa *et al.* (2018) and Srivastava *et al.* (2020).

Number of leaves per plant

The genotype G60 (IC-35583) was having highest number of leaves with 185.8, followed by G59 (IC-35582) with 172.47 leaves and genotype G53 (IC-35576) was lowest with 153.13 leaves (Table 1). These findings are supported by Dinssa *et al.* (2018) and Bashyal *et al.* (2022).

Leaf length (cm)

The genotype G55 (IC-35578) was having longest leaf length with 13.22 cm, followed by G56 (IC-35579) with 12.46 cm and genotype G51 (IC-35574) was having shortest leaf length with 7.10 cm (Table 1). These findings are supported by Kumar *et al.* (2019) and Bashyal *et al.* (2022).

Table 1. Mean performance and range of 12 (10+2 control) genotypes for 15 characters.

Genotype	Days to 50% flowering	Plant height (cm)	Inflores-cence length (cm)	Stem diameter (cm)	No. of primary branches per plants	No.of leaves per plant	Days to maturity	Seed yield per plant (gm)	Seed yield per plot (gm)	Seed yield per ha. (q)	Leaf length (cm)	Leaf breadth (cm)	Biological yield (gm)	Harvest index (%)	Test weight of seeds (gm)	Leaf area (cm^2)	Fiber content (%)	Oil content (%)
G51	61.43	86.27	38.22	0.92	17.19	120.73	118.1	6.24	73.46	8.16	7.10	4.46	52.19	11.95	0.58	22.86	4.94	4.53
G52	60.43	101.37	37.07	0.86	20.22	131.8	125.23	9.44	111.15	12.35	11.52	6.11	49.38	19.11	0.51	35.63	4.26	4.83
G53	64.10	76.77	37.95	0.81	19.27	115.4	102.49	11.41	134.64	14.96	8.75	3.18	47.27	24.16	0.48	14.38	5.24	6.23
G54	54.10	95.47	36.58	1.04	17.24	116.73	129.27	9.71	114.89	12.76	10.45	8.07	69.22	14.03	0.74	32.04	7.72	8.23
G55	65.50	119.87	34.49	1.20	23.89	126.2	127.65	13.47	153.34	17.03	13.22	8.11	82.97	16.24	0.80	42.67	6.45	7.57
G56	61.86	77.67	38.25	1.18	12.66	153.13	107.26	12.51	151.23	16.8	12.46	7.05	66.94	18.69	0.44	38.76	6.59	5.73
G57	50.43	87.10	41.04	0.96	21.69	144.33	115	7.87	91.37	10.15	8.57	5.83	54.7	14.42	0.63	25.96	6.26	4.23
G58	56.10	100.07	39.44	1.09	25.04	128.4	103.82	11.16	132.71	14.74	10.25	4.86	73.12	15.27	0.54	24.73	5.11	6.30
G59	63.10	86.83	28.47	0.84	26.18	172.47	112.01	8.17	95.37	10.59	10.15	7.76	69.22	11.81	0.67	18.71	4.94	4.30
G60	48.80	90.17	49.57	0.94	27.39	185.8	120.48	13.8	162.72	18.07	11.43	6.19	78.31	17.62	0.75	20.17	4.66	4.80
Pusa Kirti	57.83	107.13	11.66	0.55	9.46	157.4	118.33	2.63	78	8.66	8.47	3.81	60.44	4.35	0.58	18.03	7.02	7.17
Pusa Kiran	55.83	113.86	16.05	0.84	12.65	179.07	114.23	2.93	85.4	9.48	11.69	5.25	56.03	5.23	0.61	23.13	6.85	6.57
Mean	58.03	95.21	34.06	0.94	19.41	144.29	116.16	9.11	115.36	12.81	10.34	5.89	63.32	14.41	0.61	26.42	5.84	5.88
Max	65.50	119.87	49.57	1.20	27.39	185.8	129.27	13.8	162.72	18.07	13.22	8.11	82.97	24.16	0.75	42.67	7.72	8.23
Min	48.80	76.77	28.47	0.81	9.46	115.4	102.49	2.63	73.46	8.16	7.10	3.18	47.27	4.35	0.44	14.38	4.26	4.23
SEm±	1.41	1.66	1.33	0.04	1.87	1.11	1.65	0.096	0.66	0.07	0.64	0.17	0.54	0.19	0.027	0.11	0.12	0.21
CD (P=0.05)	4.12	4.88	3.89	0.02	5.49	3.26	4.85	0.28	1.95	0.21	1.87	0.50	1.59	0.57	0.08	0.32	0.36	0.83
CV	4.19	3.02	6.75	7.27	16.72	1.34	2.46	1.83	0.99	0.99	10.70	5.06	1.48	2.32	7.75	0.73	3.58	6.11

Leaf breadth (cm)

The genotype G55 (IC-35578) was highest in leaf breadth i.e., 8.11 cm, followed by G58 (IC-35581) 8.07 cm and genotype G53 (IC-35576) was having lowest leaf breadth i.e., 3.18 cm (Table 1). These findings are supported by Kumar *et al.* (2019) and Bashyal *et al.* (2022).

Leaf area (cm²)

The genotype G55 (IC-35578) was largest with 42.67 cm², followed by G56 with 38.76 cm² and genotype G53 (IC-35576) was smallest with 14.38 cm² (Table 1). These findings are supported by Chaudhari *et al.* (2010) and Managa and Nemadodzi (2023).

Days to maturity

The genotype G53 (IC-35577) was first one to get matured with 102.49 days after sowing, followed by G58 (IC-35581) with 103.82 days and genotype G54 (IC-35576) was last one with 129.27 days to maturity (Table 1). These findings are supported by Dinssa *et al.* (2018) and Bhalekar *et al.* (2019).

Seed yield per plant (gm)

The genotype G60 (IC-35583) was having highest yield with 13.8 gm, followed by G55 (IC-35578) with 13.47 gm and genotype. Pusa Kirti was having lowest yield with 2.63 gm (Table 1). These findings are supported by Kumar and Yassin (2014) and Bhalekar *et al.* (2019).

Seed yield per plot (gm)

The genotype G60 (IC-35583) was having highest yield with 162.72 gm, followed by G55 (IC-35579) with 153.34 gm and genotype G51 (IC-35574) was having lowest yield with 73.46 gm (Table 1). These findings are supported by Bhalekar *et al.* (2019) and Bashyal *et al.* (2022).

Seed yield per hectare (q/ha)

The genotype G60 (IC-35583) was having highest yield with 18.07 q/ha, followed by G55 (IC-35578) 17.03 q/ha and genotype G51 (IC-35574) was having lowest yield with

Table 2. Pearson correlation coefficient across the variables.

	DTF	PH	IL	SD	NPB	NLP	LL	LB	LA	DTM	TWS	BY	HI	FC	OC	SYP	SYPL	SYPH
DTF	1	0.002^{NS}	-0.218^{NS}	0.074^{NS}	-0.120^{NS}	-0.385^{NS}	0.105^{NS}	0.093^{NS}	0.252^{NS}	-0.152^{NS}	-0.283^{NS}	-0.111^{NS}	0.215^{NS}	-0.128^{NS}	0.122^{NS}	0.093^{NS}	0.039^{NS}	0.039^{NS}
PH		1	-0.513^{NS}	-0.029^{NS}	-0.089*	0.091^{NS}	0.409^{NS}	0.224^{NS}	0.344^{NS}	0.518*	0.455^{NS}	0.316^{NS}	-0.521*	0.308^{NS}	0.524^{NS}	-0.276^{NS}	-0.106^{NS}	-0.107^{NS}
IL			1	0.601*	0.648*	-0.277^{NS}	0.079^{NS}	0.265^{NS}	0.231^{NS}	-0.015^{NS}	0.079^{NS}	0.202^{NS}	0.790*	-0.476^{NS}	-0.379^{NS}	0.808**	0.605*	0.605*
SD				1	0.359^{NS}	-0.282^{NS}	0.556^{NS}	0.655*	0.747**	0.061^{NS}	0.193^{NS}	0.545^{NS}	0.460^{NS}	0.081^{NS}	0.120^{NS}	0.715*	0.631*	0.631*
NPB					1	0.020^{NS}	0.164^{NS}	0.576^{NS}	0.079^{NS}	0.025^{NS}	0.447^{NS}	0.457^{NS}	0.456^{NS}	-0.609*	-0.379^{NS}	0.622*	0.442^{NS}	0.442^{NS}
NLP						1	0.268^{NS}	0.196^{NS}	-0.250^{NS}	-0.079^{NS}	0.175^{NS}	0.235^{NS}	-0.435^{NS}	-0.033^{NS}	-0.315^{NS}	-0.227^{NS}	-0.033^{NS}	-0.033^{NS}
LL							1	0.628*	0.671*	0.247^{NS}	0.245^{NS}	0.574*	0.200^{NS}	0.131^{NS}	0.290^{NS}	0.491^{NS}	0.655*	0.655*
LB								1	0.665*	0.009^{NS}	0.258^{NS}	0.690^{NS}	0.121^{NS}	-0.195^{NS}	-0.142^{NS}	0.481^{NS}	0.436^{NS}	0.436^{NS}
LA									1	0.255^{NS}	0.003^{NS}	0.373^{NS}	0.249^{NS}	0.080^{NS}	0.162^{NS}	0.443^{NS}	0.431^{NS}	0.431^{NS}
DTM										1	0.674^{NS}	0.247^{NS}	-0.197^{NS}	0.232^{NS}	0.265^{NS}	-0.023^{NS}	-0.064^{NS}	-0.064^{NS}
TWS											1	0.649*	-0.224^{NS}	0.220^{NS}	0.242^{NS}	0.153^{NS}	0.132^{NS}	0.131^{NS}
BY												1	-0.012^{NS}	0.161^{NS}	0.314^{NS}	0.524*	0.595*	0.595*
HI													1	-0.448^{NS}	-0.179^{NS}	0.842**	0.707*	0.708*
FC														1	0.724*	-0.299^{NS}	-0.140^{NS}	-0.140^{NS}
OC															1	-0.012^{NS}	0.181^{NS}	0.180^{NS}
SYP																1	0.925**	0.925**
SYPL																	1	1.000**
SYPH																		1

In **Table 2.-** DTF is Days to 50% flowering, PH is Plant height, IL is Inflorescence length, SD is Stem diameter, NPB is Number of primary branches per plant, NLP is Number of leaves per plant, LL is Leaf length, LB is Leaf breadth, LA is Leaf area, DTM is Days to maturity of seeds, TWS is Test weight of seeds, HI is Harvest index, SYP is Seed yield per plant and SYPH is Seed yield per hectare, NS, Non-significant, *significant at 0.05, **significant at 0.01.

8.16 q/ha (Table 1). These findings are supported by Bhalekar *et al.* (2019) and Bashyal *et al.* (2022).

Test weight (gm)

The genotype G55 (IC-35578) was highest with 0.80 gm, followed by genotype G60 (IC-35578) with 0.75 gm and genotype G56 (IC-35579) was lowest with 0.44 gm (Table 1). These findings are supported by Dinssa *et al.* (2018) and Kumar *et al.* (2019).

Biological yield (gm)

The genotype G55 (IC-35578) was highest with 82.97 gm, followed by G60 (IC- 35583) with 78.31 gm and genotype G53 (IC-35576) was lowest with 47.27 gm (Table 1). These findings are supported by Rana *et al.* (2020) and Srivastava *et al.* (2020).

Harvest index (%)

The genotype G53 (IC-35576) was highest with 24.16 %, followed by G52 (IC-35575) with 19.11 and genotype Pusa Kirti was lowest with 4.35 % (Table 1). These findings are supported by Jangir *et al.* (2019) and Rana *et al.* (2020).

Fiber content (%)

The genotype G54 (IC-35577) was highest with 7.72 %, followed by genotype Pusa Kirti with 7.02 % and genotype G52 (IC-35575) was lowest with 4.26% (Table 1). These findings are supported by Dinssa *et al.* (2018) and Singh and Punia (2020).

Oil content (%)

The genotype G54 (IC-35577) was highest with 8.23 %, followed by G55 (IC-35578) with 7.57 % and G57 (IC-35580) was lowest with 4.23 % (Table 1). These findings are supported by Garcia and Diaz (2019) and Singh and Punia (2020).

Pearson correlation coefficient

Correlation coefficient studiess(Table 2) revealed that-

- Days to 50% flowering did not exhibit any significant correlation association. Plant height showed significant and positive correlation association with days to maturity (r = 0.518*). Inflorescence length showed highly significant and positive correlation association with seed yield per plant (r = 0.808**) and, showed significant and positive correlation association with stem diameter (r= 0.601*), number of primary branches (r=0.648*), harvest index (r = 0.790*), seed yield per plot (r=0.605*) and seed yield per hectare (r=0.605*). Stem diameter showed highly significant and positive correlation association with leaf area (r = 0.747**) and showed significant and positive correlation association with leaf breadth (r = 0.655*), seed yield per plant (r = 0.715*), seed yield per hectare (r =605*). Number of primary branches showed significant and positive correlation association seed yield per plant (r = 0.622*) and, showed significant and negative correlation with fiber content (r=0.622). Number of leaves per plant did not exhibit any significant correlation association. Leaf length showed significant and positive correlation association with leaf area (r = 0.671*), seed yield per plot (r=0.655*), seed yield per hectare (r=0.655*),

Table 3. Morphological characters of (10+2 control) genotypes of amaranth.

Genotypes	Leaf Color	Stem Color	Inflorescence Color	Seed Color
G51	GREEN	REDDISH PINK	RED	CREAMISH YELLOW
G52	GREEN	LIGHT GREEN	LIGHT GREEN	CREAMISH YELLOW
G53	GREEN	LIGHT GREEN	LIGHT GREEN	CREAMISH YELLOW
G54	GREEN	LIGHT GREEN	LIGHT GREEN	CREAMISH YELLOW
G55	GREEN	LIGHT GREEN	LIGHT GREEN	CREAMISH YELLOW
G56	GREEN	REDDISH PINK	RED	CREAMISH YELLOW
G57	GREEN	LIGHT GREEN	LIGHT GREEN	CREAMISH YELLOW
G58	GREEN	LIGHT GREEN	LIGHT GREEN	CREAMISH YELLOW
G59	GREEN	LIGHT GREEN	LIGHT GREEN	CREAMISH YELLOW
G60	GREEN	LIGHT GREEN	LIGHT GREEN	CREAMISH YELLOW
Pusa Kirti	RED	RED	RED	BLACK
Pusa Kiran	GREEN	GREEN	GREEN	BLACK

leaf breadth (r=0.628*) and biological yield (r=0.574*). Leaf breadth showed significant and positive correlation association with leaf area (r =0.665*). Leaf area did not exhibit any significant correlation association. Days to maturity of seeds did not exhibit any significant correlation association. Test weight of seeds showed significant and positive correlation association with biological yield (r = 0.605*). Harvest index showed highly significant and positive correlation associationwith seed yield per plant (r = 0.842**) and, and significant and positive correlation with seed yield per plot (r = 0.707*) and seed yield per hectare (r=0.708*). Fiber content showed significant and positive correlation association with oil content (r = 0.724*). Seed yield per plant showed highly significant and positive correlation association with seed yield per plot (r = 0.925**) and seed yield per hectare (r = 0.925**). Seed yield per plot showed highly significant and positive correlation association with seed yield per hectare (r = 1.0*).

Conclusion

From the above results it is concluded that the genotype G60 (IC – 35583) has shown best performance for Parameters like Days to 50% Flowering, Inflorescence length (cm), Stem Diameter (cm), Number of Branches per plant, Number of leaves per plant, Seed Yield per plant (gm), Seed Yield per hectare (q), followed by G55 (IC – 35578) for Leaf Length (cm), Leaf Breadth (cm), Leaf area (cm^2) and Plant Height as compared with check variety Pusa Kirti and Pusa Kiran. Also, G54 (IC-35577) can be considered for its high fiber and oil content. Whereas, G53 (IC-35576) can be used as an early maturing variety with comparatively higher Harvest Index.

Correlation coefficient studies concluded that Inflorescence length, stem diameter, number of branches per plant, leaf length, biological index and harvest index showed significant and positive correlation association with seed yield.

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