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Evaluation and characterization of leafy vegetables (*Amaranthus* spp.) grown in Chhattisgarh: A review

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Abstract

The present investigation entitled "Evaluation and Characterization of Leafy Vegetables (*Amaranthus* spp.) grown in Chhattisgarh." was conducted at Research and Instructional Farm, Department of Horticulture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during the experiment 1 conducted during *rabi* season of 2014-2015 and 2015-16 while experiment 2 was conducted during *kharif* season of the both year. Amaranth is one of the main species of the large and taxonomically diverse group of tropical leaf vegetables. It is a fast growing crop with a high yield potential in a short period and suitable for crop rotation with any other vegetable crop. Because of its low production costs, amaranth is one of the cheapest dark-green leafy vegetables in tropical markets and is often described as the poor man's vegetable. The nutritional value of amaranth is excellent because of its high content of essential micronutrients: amaranth leaves are a good source of ß -carotene, iron, calcium, vitamin C and folic acid. Amaranth belongs to the genus Amaranthus of the family Amaranthaceae. Amaranthus has many species which are used as leafy vegetables, the green Amaranthus consist of approximately 60 species out of which about 18 species are occurring in India. There are three major producing *Amaranthus species, A. caudatus, A. cruentus* and *A. hypochondriacus*, all believed to originate from Central and South America; and three major leafy vegetable species, *A. tricolor, A. dubius* and *A. blitum* (*A. lividus*), of which A. tricolor is thought to originate from India or Southern China, *A. blitum* from Central Europe and *A. dubius* from Central America (Yadav *et al.,* 2014).

Keywords: Characterization, leafy vegetables, *Amaranthus* spp.

1. Introduction

Chaulai (*Amaranrhus viridis* L.) and Khedha (*Amaranrthus dubius* Mart.) are leafy vegetables locally known as chaulai bhaji (lal & green) and Khedha bhaji (jari) belongs to the family Amranthaceae. The plant height varies from 0.3 m to 5m among various species. Leaves are oblong to elliptical with color ranged from light to dark green with some expressing red pigment throughout the genus. Pollination is predominantly autogamous in amaranth. Its flowers are unisexual, small, with stamens at the apex of the glomerules and pistils. The inflorescence is very prominent, colorful, terminal and contain one male flower per glomerule. India is the largest producer of vegetable crops next to China. Leafy vegetables are cultivated in an area of 9205 thousand hectare with an annual production of 162187 thousand MT (Anon. 2013) [8].

In Chhattisgarh, vegetables occupied an area of 377.21 thousand hectare with an average production of 4965.33 thousand MT out of these, leafy vegetables are cultivated in an area of 7688 hectare with an average production of 72902 MT (Anon., 2014) [8]. Despite such a huge production in the country, less than the appropriate requirement of balanced diet is provided to every individual. In Chhattisgarh, the life and economy of the tribal and local people are intimately connected with the natural vegetation. Leafy vegetables play a major role in the nutritional requirement of the tribal and local population in remote parts of the Chhattisgarh.

The use of leafy vegetables as food has been formed an integral part of the culture and tradition of many indigenous communities of the world. It constitutes an essential component in the diet and food security of many tribal and local communities particularly people living around the forest fringe. It is estimated that in India about 800 species are consumed as wild edible plants over the country (Singh and Arora, 1978) [72]. Wild edible plants are not only providing food in sufficient quantity but also makes significant contribution to the population nutrition throughout the year (Grivetti and Ogle Britta, 2000; Ogle Britta *et al*., 2003) [29, 51].

Fifty one such leafy vegetables are available in this region that are eaten by the tribal and local people of Chhattisgarh. Wild plants such as, Amaranthus species, *Borhaavia diffusa*, *Basell rubra*, *Cleome gynandra*, Chenopodium species Corchorus species, *Leucas cephalotes*, *Hibiscus cannabinus*, and *Trianthema portulacastrum* are very popular and still are widely available in the communities. Looking to the various types of leafy vegetables grown in Chhattisgarh i.e. Amari Bhaji, Tinpania Bhaji, Bathua Bhaji, Chaulai Bhaji, Chech Bhaji, Chunchunia Bhaji, Karmota Bhaji, Lal Bhaji, Methi Bhaji, Palak, Patawa Bhaji, Patharri Bhaji, Poi Bhaji, Sarson Bhaji, Jadi Bhaji, Bohar Bhaji and rapid urbanization of developing country like India, food security is a major concern (Chauhan *et al*., 2014) [17]. In Chhattisgarh state, leafy vegetables are found naturally in both cultivated and non-cultivated lands and there are major dietary component of tribal as well as rural people of the state. The tribal are normally collected seeds from local forest product and sell them to sustain their livelihood. Also the diversity of leafy vegetable species offer variety in family diet and contribute to household food security as well as increases dietary diversity. Further, it provides rural households with supplemental income opportunities through their sale in the markets. The US national institute reported that food is rich in vitamins A and C there have been associated with reduced risk of certain cancers. Leafy greens are very low in calories and sodium; and are free of fat and cholesterol. Vegetable amaranth serves as an alternative source of nutrition for people in developing countries since it is a rich and inexpensive source of carotenoid, protein, vitamins and dietary fibre (Prakash and Pal, 1991; Shukla *et al*., 2003) [52, 69]. It has been rated equal or superior in taste to spinach and is considerably higher in protein (14 - 30% on dry weight basis), minerals (Fe, Mn and Zn), antioxidants like beta-carotenoid (90 - 200 mg kg-1) and ascorbic acid (about 28 mg/100 g) compared to any other leafy vegetables. Antioxidant neutralizes or removes free oxygen radicals in the body and help to protect many diseases including cancer, cardiovascular diseases, neurodegenerative diseases and inflammation and prevent aging. Amaranth vegetables contribute greatly to the nutritional well-being of rural people by providing the essential nutrients required for body growth and development and for prevention of diseases associated with nutritional deficiencies such as blindness due to vitamin A deficiency. Amaranthus species are being cultivated since centuries as a leafy vegetable; it is characterized by a high degree of diversity and a wide spectrum of adaptability to different agro ecological conditions (Snezana *et al*. 2012w; Katiyar *et al*. 2000; Shukla and Singh 2000) [73, 37, 44]. Amaranth uses the C4 cycle photosynthetic pathway. It has a high rate of photosynthesis and excellent water use efficiency at high temperatures and high radiation intensity.

2. Review of Literature

1. Performance of genotypes
2. Genetic variability
3. Heritability and genetic advance
4. Genetic divergence
5. Correlation coefficient studies
6. Path coefficient analysis

3.1 Performance of genotypes

Shukla *et al*. (2006) [70] grown twenty nine strains of vegetable amaranthus (*Amaranthus tricolor* L.) for two successive seasons to study different selection parameters for foliage yield and its nine contributing morphological and quality traits. The strains AV-38 (5.06 kg plot^{-1}) and AV-31 (5.04 kg plot^{-1}) recorded highest foliage yield, followed by AV-30 (4.78 kg plot^{-1}) and AV-23 (4.70 kg plot^{-1}).Gimplinger *et al*. (2007) studied two genotypes of Amaranthus (*A. hypocondriacus* and *A. cruentus*) and reported that average hand harvested yields ranged from 2200 to 3000 kg ha^{-1} without significant genotypic differences. Priya *et al*. (2007) [58] studied sixty diverse genotypes of amaranthus and found significant difference among genotypes for all the characters studied. The highest yield was recorded from accession A 57 (304.5 g plant^{-1}) followed by A 53. Whereas, NBPGR accession A 9 was the lowest yielder. Gabriela *et al.* (2010) [23] studied six popular spp. of Amaranthus for different geographic region using RAPD marker and reported that using ITS primers type that amplified characteristic fragments from rDNA region after amplification a single product was obtained for all *Amaranthus* samples. From the RAPD data, an UPGMA dendrogram illustrating a difference between wild species of *Amaranthus (A. chlorostacys powellii)* and the other two species examined. In addition, between *A. hyponchondriacus* and *A. cruentus* there is a relationship, the genetic distance between them being ~18-20%.

Celini *et al*. (2011) [16] studied thirty two accessions of *A. dubius* and found that the accession AD 23 had highest yield (382.0 g plant^{-1}) which was closely 5 followed by AD 13 and AD 18 in the first year. Mandal *et al*. (2012) [42] studied seventeen genotypes of Amaranthus including four improved varieties and 13 local types. A wide range of variation was observed for yield ha^{-1} (55.8 to 303.9 q ha^{-1}). Among the genotypes, Bankura Collection 3 (303.9 q ha^{-1}) and Bolpur Collection 1 (287.0 q ha^{-1}) produced highest yield ha^{-1}, followed by Pusa Kirti (283.5 q ha^{-1}). Evaluated 89 Amaranthus accession and reported that all *Amaranthus dubius* Mart. ex. Thell. and *A. hypochondriacus* L. accession were resistant under field conditions; the *A. tricolor* L. accession exhibited various degrees of symptoms.

3.2 Genetic variability

Genetic variability is the raw material on which selection acts to evolve superior genotypes or varieties in plant breeding programme. The genetic variability for various characters available in the breeding populations or materials is systematically subjected to selection to change the genetic architecture of plant characters and consequently of the plant as a whole to develop improved genotype having higher economic yield. The reservoir of variability for different characters of a plant species resulting from available natural or artificially synthesized variants or strains constitutes its germplasm. Thus, germplasm may include improved strains, primitive cultivars, wild relatives, obsolete cultures, special genetic stocks, seeds pollen and vegetative parts etc. Most of the germplasm collections are inadequately evaluated or screened for assessment of genetic variability. Varalaksmi and Reddy (1994) [79] evaluated twenty five lines of vegetable amaranth and found high genotypic coefficient of variation for number of leaves, leaf weight, stem weight, leaf-stem ratio and yield of greens per plant. Revanappa and Madalgeri (1998) [62] evaluated 40 genotypes of amaranthus and reported that phenotypic coefficient of variability is higher than genotypic coefficient of variability. The PCV and GCV were maximum for leaf stem ratio, no of leaves and fresh weight of leaves while, it was minimum for stem girth.

Wu *et al.* (2000) [85] studied 229 genotypes of 20 *Amaranthus species* and observed wide variability for plant height, maturity, leaf number and color, stem color, seed color, branch number, 1000 grain weight, yield per plant and resistance to stresses (including diseases). Shukla *et al*. (2004) [67] reported that the strains AV-38 (5.06 kg plot^{-1}) and AV-31 (5.04 kg plot^{-1}) recorded highest foliage yield, followed by AV-30 (4.78 kg plot^{-1}) and AV-23 (4.70 kg plot^{-1} Varalakshmi *et al*. (2004) [77] evaluated 46 accessions of amaranthus during the *kharif* season. The germplasm showed a wide range of variability in plant height (31-81.5 cm), length of basal lateral branches (2.3-103 cm), length of top branches (5-58.3 cm), leaf width (3-12 cm), petiole length (3-9 cm) and inflorescence length (5-50 cm), inflorescence lateral length (2.5-32.6 cm), length of auxiliary branches (0.2-5 cm) and days to 50% flowering (29-69).

Studied ten genotypes of amaranthus and found wide range of variability in plant height, foliage per plant, average foliage length, foliage width, foliage mass plant^{-1} and seed mass plant^{-1}. Shukla *et al*. (2006) [70] evaluated twenty nine strains of vegetable amaranthus (*Amaranthus tricolor* L.) and found that genotypic coefficient of variation (GCV) values ranged from 6.80 to 28.25%. However, the fibre content, branches plant^{-1}, leaves plant^{-1}, plant height and stem diameter showed lowest values of GCV. Vyas *et al*. (2006) [83] studied genetic variability for ten characters in 60 genotypes of amaranthus and revealed the presence of considerable amount of genetic variability for all characters. Anuja and Mohideen (2007) [12] studied genetic variability for hundred genotypes of amaranthus and found that there were highly significant differences between the genotypes for green yield and thirteen other characters. The values of PCV were higher as compared to GCV due to the influence of environment. High genotypic coefficient of variation was observed for number of leaves, yield of greens, root weight, leaf weight, stem weight and leaf area.

Oboh (2007) [49] studied 16 accession of *Amaranthus hybrida* and reported wide range of variability in the most of the quantitative characters assessed with variability in plant height ranging (74.30 - 181.00 cm), leaf length (13.90 – 29. 40 cm) and leaf width from (7.00 – 12.40 cm). Pan *et al.* (2008) [53] studied twenty four indigenously collected germplasm of vegetable amaranth (*A. tricolor*) for all the nine quantitative characters. The maximum extent of genetic variability was exhibited by leaf-stem ratio followed by total yield of greens per plot, girth of stem and length of leaf. Joshi *et al*. (2011) [36] observed thirty one accessions of amaranthus and found that germplasm showed a wide range of variability in plant height (46.0-149 cm), number of branches (5.5-20.5), leaf length (10.0-24.5 cm), leaf width (5.2-12.7 cm), petiole length (5.7-12.7 cm) leaf weight per plant (7.0-119.0 g), stem weight per plant (28.0-975.0 g) and seed yield per plant (6.0-58.0 g). Ahammed *et al*. (2012) [12] studied twenty two genotypes of stem amaranthus and reported that the highest PCV (87.85%) and GCV (81.67%) were observed for primary branches per plant while the lowest PCV (10.28%) was found in plant height and the lowest GCV (7.51%) was found in leaf width. Mandal *et al*. (2012) [42] studied seventeen genotypes of Amaranthus including four improved varieties and 13 local types. Significant differences were observed among the entries for all the studied characters *i.e*. plant height, stem girth, number of leaves plant^{-1}, leaf length and width, leaf and stem fresh weight, leaf-stem ratio, yield plant^{-1} and yield hectare^{-1}.

Akaneme and Ani (2013) [7] studied genetic variability in five accessions of the *Amaranthus hybridus* and revealed highly significant differences for leaf width, hypocotyls length, days to 50% flowering, 500 seed weight and leaf length. Phenotypic and genotypic coefficients of variability also revealed high variability for each of the quantitative traits. Hasan *et al.* (2013) [6] The genotypes varied significantly for all the characters studied. High GCV and PCV were observed in leaf weight (77.54 and 80.14%, respectively) and dry weight without rind (74.42 and 74.47% respectively). conducted an experiment on genetic variability in twenty four genotypes of *Amaranthus* spp. and observed that the analysis of variance was highly significant differences for all the parameters. Phenotypic coefficient of variation (PCV) was higher than those of genotypic coefficient of variation (GCV) in both seasons for all the characters in all the cuttings. Selvan *et al.* (2013) [66] evaluated ten genotypes of grain amaranthus (*Amaranthus hypochondriacus*). The result revealed that the GCV was maximum in high plant density when compared to very high, normal and low plant density level for the characters *viz.*, fresh weight of the inflorescence, grain yield plant^{-1} and total carbohydrates.

Gerrano *et al.* (2014) [26] studied 32 genotypes *Amaranthus* spp. and reported the analysis of variance showed highly significant differences among the *Amaranthus species* for all phenotypic traits, indicating the existence of high genetic variability. Patial *et al*. (2014) [57] twenty two genotypes of amaranth (*Amaranthus* spp.) were evaluated and found that the low differences between the phenotypic and genotypic coefficients of variations indicated low environmental influences on the expression of the traits studied. Vujacis *et al*. (2014) [82] studied ten amaranth genotypes of amaranth and found that significant variability in total leaf mass plant^{-1} ranging from 94.05 g to 246.81 g, grain yield plant^{-1} ranging from 45.56 g to 67.55 g, as well as total grain yield ranging from 2220 kg ha^{-1} to 3200 kg ha^{-1} Abe *et al*. (2015) [1] evaluated thirty two amaranthus genotypes were and revealed that genotypes exhibited great variability with highly significant differences in phenotypic characteristics.

3.3 Heritability and genetic advance

The term heritability in broad sense can be defined as the ratio of genetic variance to the total phenotypic variance (Lush, 1940) [41]. It is generally expressed in percentage. Thus the heritability is the heritable portion of phenotypic variance which is good index of the transmission of characters from parents to their offspring (Falconer, 1960) [20]. Depending upon the components of variance used as numerator in the calculation, heritability is of two types *viz.*, broad sense heritability and narrow sense heritability. Heritability estimate provides the information regarding the amount of transmissible genetic variation to total variation and determines genetic improvement and response to selection. Johnson *et al*. (1955) [35] emphasized that heritability estimates, when studied in conjunction with genetic advance would provide more appropriate information than the study of heritability alone. Thus, the estimates of heritability and genetic advance are of great significance to the plant breeders for developing suitable selection strategy. Revanappa and Madalgeri (1998) [62] evaluated 40 genotypes of Amaranthus and observed high heritability for the most of the character but genetic advance was high for green yield plant^{-1} (61.07%) and other yield parameters. Genetic advances (1.06%) were noticed for total chlorophyll content which is one of the quality traits.

Rani and Veeraragavathatham (2003) [60] evaluated fifty-seven lines of Amaranthus (*Amaranthus* spp.) and observed heritability ranged from 73.33 to 97.00%. High heritability coupled with high genetic advance and obtained for green yield plant^{-1} (92.56 and 161.36%), stem weight plant^{-1} (97.00 and 152.40%), leaf number plant^{-1} (91.31 and 107.65%) and leaf weight plant^{-1} (89.94 and 108.77%) followed by the other traits such as plant height (85.93 and 44.37%), leaf length (82.68 and 47.80%), leaf breadth (74.26 and 45.72%) and stem girth (73.33 and 47.87%), which suggested additive gene effects controlling these traits. Shukla *et al*. (2005a) evaluated 29 strains of vegetable amaranth (*A. tricolor*) and observed the heritability estimates were in general high for all the characters in the entire cuttings and ranged from 74.87% to 93.33%. Genetic advance was maximum for foliage yield (42.50%) followed by leaf size (31.02%) and stem diameter (21.13%). Shukla *et al*. (2006) [70] studied twenty nine strains of vegetable amaranth (*Amaranthus tricolor* L.). The high heritability was estimates for all the traits in all the cuttings as well as on pooled basis. Highest expected genetic advance was noticed for ascorbic acid (57.48%) followed by foliage yield (48.30%) and leaf size (29.51%). Anuja and Mohideen (2007a) [12] studied genetic variability and heritability in 100 genotypes of Amaranthus germplasm and found heritability estimates in general were high for most of the characters. High heritability coupled with high genetic advance (as percent of mean) was observed for number of leaves, root length, root weight, leaf weight and stem weight. Pan *et al*. (2008) [53] evaluated 24 indigenously collected germplasm of *A. tricolor* including two released varieties and found that heritability was high for leaf stem ratio, width of leaf, length of leaf, days to 1st clipping, number of clipping, girth of stem and total yield of greens plot^{-1}.

Ahammed *et al.* (2013) [2] evaluated 22 genotypes of stem amaranth and found heritability estimates in broad sense were higher for leaf weight plant^{-1} (91.10%) followed by leaves plant^{-1} (86.83%), primary branches plant^{-1} (86.42%), stem weight plant^{-1} (82.56%) and yield ha^{-1} (78.70%). Leaf weight plant^{-1}, stem weight plant^{-1} and yield ha^{-1} exhibited high value of heritability (91.10%, 82.56% and 78.70% respectively) along with high genetic advance 49.38%, 134.12% and 56.00% for leaves plant^{-1}, stem diameter and stem weight plant^{-1}, respectively. Hasan *et al*. (2013) [6] evaluated seventeen genotypes of stem amaranth (*Amaranthus tricolor* L.) and observed high heritability coupled with high genetic advance as percent of mean was recorded for number of leaf, leaf weight and marketable yield which it reflected the presence of additive gene effects. Patial *et al*. (2014) [57] evaluated twenty two genotypes of amaranthus (*Amaranthus* spp.). High heritability coupled with high genetic advance for yield plant^{-1}, day to maturity, day to seed fill, harvest index, panicle girth and seed yield plant^{-1} were observed.

Venkatesh *et al.* (2014 b) [81] studied on hundred germplasm accessions of grain amaranth, all the traits studied exhibited high heritability. High genetic advance as percent of mean was observed for days to 50 percent flowering, stem girth, number of leaves plant^{-1}, plant height, panicle length, panicle width and grain yield plant^{-1}. Vujacic *et al* (2014) [82] studied ten amaranth genotypes and observed that heritability varied from 86% (grain weight plant^{-1}) to 92% (leaf mass plant^{-1}).Yadav *et al.* (2014) [87] evaluated twenty seven grain amaranth germplasm, the estimates of heritability were observed to be high in magnitude for days to 80% maturity, days to 50% flowering, leaf blade width, inflorescence length and plant height. Abe *et al*. (2015) [1] evaluated thirty two amaranthus genotypes and revealed that the heritability estimates in broad-sense ranged from 2.21 to 99.78. The thousand seed weight showed the highest heritability (99.78) value, whereas the lowest was observed in leaf area index (2.21).

3.4 Genetic divergence

The concept of D^2 statistics was originally developed by Then Rao (1952) [61] suggested the application of this technique for the arrangement of genetic diversity in plant breeding. Now, this technique is extensively used in vegetable breeding for the study of genetic divergence in the various breeding material including germplasm. This analysis also helps in the selection of diverse parents for the development of hybrids. Cluster analysis helps to form groups of closely related individuals which help in determining genetic distance between them. Rana *et al*. (2005) [59] studied one hundred accessions of grain amaranth (*Amaranthus hypochondriacus*) germplasm for six quantitative and two qualitative characters. All the genotypes were grouped into 10 different clusters. Clusters I, VII, VIII, IX and X had high genetic distance with all other clusters. Pandey (2009) [54] evaluated twenty six accessions of grain amaranths (*Amaranthus hypochondriacus*). All the accessions were grouped into eleven clusters. Clusters I, II, and III had seven, four, and three accessions, respectively. Clusters VII, VIII, IX and X had only one accession in each case. The accession in cluster V had the greatest divergence, closely followed by those of clusters IV and I. The maximum and minimum divergences were revealed between clusters VIII and XI and between II and VII, respectively.

Pandey and Singh (2011) [39] studied genetic divergence in 98 genotypes of grain amaranth (*Amaranthus hypochondriacus* L.) for 14 characters. Genotypes were grouped into 18 clusters in which cluster I contained maximum number of genotypes (42), Cluster II (11), Cluster III (7), Cluster IV and V (5 in each case) and Cluster VI has 4 genotypes. Cluster VII, VIII, IX, X have (3 in each), cluster XI, XII, XIII, XIV (2 in each) and clusters XV, XVI, XVII and XVIII (1 in each case). Erum *et al.* (2012) [19] evaluated 13 Amaranthus genotypes (*A. hypocondricus* and *A. tricolor*) into the two major clusters, I and II, differentiating the ornamental Amaranthus cultivars form edible. The cluster showed that the *Amaranthus hypochondriacus* were closest to the china variety than to the *Amaranthus tricolor* according to their morphological characters. Optimal level of carbohydrates, fats, proteins and moisture contents were observed in 7033 (192.7 mg/ml), 7051 (30.68%) and 7033 (102.7 µg/ml) and 7034 (16%) respectively. Akaneme and Ani (2013) [7] studied five accessions of the *Amaranthus hybridus*. All the accessions divided into 2 clusters. Cluster I comprising accessions 3 and 5 and cluster II comprising accessions 1, 2 and 4. The qualitative traits differed among the accessions with the exception of growth habit, branching index and leaf shape. Akther *et al*. (2013) [6] studied seventeen genotypes of amaranthus. The genotypes under study fell into 4 clusters. The distribution pattern indicated that the maximum number of genotypes (6) was included in cluster (IV) followed by cluster III (5) and cluster II (5), and the minimum number was in cluster I (1). The highest inter cluster distance was observed between IV and I, followed by the distance between cluster II and I showing wide diversity among the groups. The lowest inter-cluster distance was observed between clusters III and II suggesting a close relationship among the genotypes of these two clusters.

Venkatesh *et al*. (2014) [81] studied one hundred genotypes and germplasm lines of grain amaranth (*Amaranthus* spp.) The genotypes were grouped into 15 distinct clusters revealing wide diversity in the experimental material. Cluster XV was largest with 18 followed by cluster XIV with 15 and cluster VIII with 11 genotypes, while cluster VI was solitary. Clustering pattern of genotypes showed lack of any relationship between geographic origin and genetic diversity. Intra cluster values ranged from 0.00 to 23.81 and cluster VII was the most diverse group. The inter cluster values ranged from 22.30 to 133.55. Maximum divergence was noticed between clusters VI and XIII (133.55) followed by clusters I and IV (132.74).

3.5 Correlations coefficient studies

Information on genetic association among various characters under particular environmental conditions may also help to formulate the most effective methods of breeding in any particular case and also to simplify the approach to selection. The study of the association of component characters with a complex trait like yield is prerequisite for any of the breeding programme. The original concept of correlation was given by Galton (1988) [24] who suggested the need of coefficient of correlation to describe the degree of association between dependent and independent variables. Later, the formula for its quantitative estimation was developed by Fisher (1918) [21] Thereafter, Searle (1961) described the mathematical implications of correlation coefficient at phenotypic, genotypic and environmental levels. Shukla and Singh (2003) [69] studied sixty six genotypes of amaranthus and found that the grain yield per plant was positively and significantly associated with plant height (0.572), number of inflorescence plant^{-1} (0.475), number of spikelet's spike^{-1} (0.45) and leaf size (0.530), which indicated that selection for these traits, would lead to an improvement in yield.

Rana *et al.* (2005) [59] studied 100 genotypes of *Amaranthus hypochondriacus*. Correlation and path analysis revealed the significance of inflorescence length, no. of leaves and plant height for selecting better yielding. Pan *et al*. (2008) [53] evaluated twenty four indigenously collected germplasm of *A. tricolor including* two released varieties and reported that the total yield of greens plot^{-1} was found to be positively and significantly correlated with duration of harvest. Studied quality traits and their direct and indirect effect on foliage yield in 39 distinct cultivars of vegetable amaranthus (*A. tricolor*). Among the agronomic traits, plant height and number of inflorescence exhibited significant positive association with foliage yield, while chlorophyll a, chlorophyll b, carotenoid, fiber and ascorbic acid were positively correlated with foliage yield.

Varalakshmi *et al*. (2010) [78] revealed that phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the traits studied, indicating environmental influence on expression of these characters. Moderate heritability along with high genetic advance was recorded for leaf weight and total plant weight, indicating the presence of additive gene effects. Hence, selection can be employed for improvement of these characters in basella. Higher plant weight was found to be significantly and positively associated with branch number, leaf number, leaf weight and stem weight. revealed that highly significant and positive correlation with green yield was observed with leaf weight, stem weight and plant height, whereas, leaf stem^{-1} ratio showed negative association with green yield in hundred genotypes of vegetable amaranth. studied twenty six amaranthus accessions and found that protein content showed a positive correlation with the number of leaves, whereas a negative correlation was observed with leaf thickness. Akaneme and Ani (2013) [7] studied five accessions of the *Amaranthus hybridus* and reported that days to 50% flowering were positively correlated with leaf length and stem diameter.

Upadhyay *et al*. (2013) [76] found that foliage yield showed positive genotypic and phenotypic association with chlorophyll a, carotenoids, fibre, protein, cadmium, nickel, chromium and manganese. However, only carotenoids and cadmium were significantly correlated with foliage yield. conducted an experiment on genetic variability in twenty four genotypes of amaranths. Total green yield exhibited highly significantly and positive correlation with plant height, number of branches plant^{-1}, leaf length, leaf width, number of leaves, and leaf area index both at genotypic and phenotypic levels and negatively correlated with oxalate content and leaf blight incidence. Hasan *et al*. (2013) [6] evaluated seventeen genotypes of stem amaranth (*Amaranthus tricolor* L.) and revealed that green yield was positive correlated with leaf weight, stem weight, stem diameter, dry weight with rind, and dry weight without rind.

Patial *et al.* (2014) [57] twenty two genotypes of amaranth (*Amaranthus* spp.) were evaluated and found that harvest index was positively correlated with days to maturity. Sarker *et al.* (2014) [65] studied genotypic variability in thirty vegetable amaranth genotypes and reported that foliage yield had significant positive correlation with plant height, leaves per plant, diameter of stem base, fibre content and leaf area. Nutrient content and antioxidant had insignificant genotypic correlations with foliage yield. Venkatesh *et al.* (2014) [81] one hundred genotypes of grain amaranth were used to estimate correlation among 10 quantitative traits including grain yield in grain amaranth. At the phenotypic level, stem girth, number of leaves per plant, plant height, panicle length and seed weight exhibited significant positive correlation with grain yield. Yadav *et al*. (2014) [87] reported that seed yield per plant showed highly significant positive correlation with days to 80% maturity and plant height and significant positive correlation with days to 50% flowering. Inflorescence length had significant positive correlation with lateral spikelet length. Abe *et al*. (2015) [1] revealed that plant height was positively correlated with fresh biomass and dry biomass. Yield per plant showed a moderate positive correlation with leaf width, leaf length, leaf area, leaf area index and plant height, and a strong correlation with fresh biomass and dry biomass.

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