# Advances in crop improvement and production technology of vegetable amaranthus (*Amaranthus spp*. L.)

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Abstract

Amaranthus is a quick growing nutritionally rich leafy vegetable crop with a high yield potential in a short period of time. In many regions of India, it is grown as a conventional leafy vegetable, using local cultivars. Intense research towards varietal development is very limited. The vegetable amaranthus being very perishable in nature and doesn't stand storage for more than a day under room temperature which restricts its export potential. The low productivity of amaranthus is due to negligence in proper cultivation and management practices, lack of advance technologies etc. A thorough knowledge regarding the amount of genetic variability existing for various characters followed by effective selection by adapting different breeding methodology is essential for initiating the crop improvement programme. The more systematic research work need to be conducted related to production technology aspects *viz*., spacing, nutrient management, pest management etc. Post harvest managements studies may help in increasing the shelf of leaves which are highly sensitive to storage life.

**Key words :** Amaranth, Crop improvement, Production technology, Post harvest management, Shelf life.

## 1. Introduction

Amaranthus (*Amaranthus spp.* L.) is a cosmopolitan genus of annual or short-lived perennial plants, belonging to Amaranthaceae family, and it originated from Central and South America. Since centuries amaranthus species are being cultivated for grain and leaf purpose, characterized by a high degree of diversity having broad adaptability to different agro ecological conditions (Snezana *et al.*, 2012).

Almost universally, amaranthus has been considered as poor people's resource (Akaneme and Ani, 2013). It substantially contribute 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. It is a highly nutritious super food rich in protein, carbohydrates, dietary fibres, calcium, iron, manganese, zinc, vitamin-A, vitamin-C, vitamin-K, riboflavin, niacin, vitamin-$B_6$ and folate which enable it to combat mal-nutrition.

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Tender stems and leaves contain the following constituents: Moisture (85.70 %), carbohydrates (6.30 g), protein (4.00 g), fat (0.50 g), calcium (397.00 mg), phosphorus (83.00 mg), iron (25.50 mg), vitamin A (9200 IU), and vitamin C (99 mg) (Rai and Yadav, 2005). Due to its nutritional superiority, amaranthus has been suggested as an alternative source of rich protein leafy vegetable and cereal feeding those over populated and under nourished areas (Dhangrah *et al.*, 2015).

Lysine and sulphur containing amino acids have been found in their leaves which many vegetables and cereal grains lack. ICMR recommends consumption of 125 g of leafy vegetables alone out of 300 g of vegetables day$^{-1}$ head$^{-1}$ (Hazra and Som, 1999). In recent few years amaranthus has been rediscovered as a promising food crop mainly due to its resistance to heat, drought, diseases and pests, and the high nutritional value of both seeds and leaves (Jangde *et al.*, 2017). It can be used as food, fodder and medicine in various pharmaceutical and cosmetics products.

In India various domesticated forms of amaranthus are grown in Tamil Nadu, Andhra Pradesh, Karnataka, Kerala, Odisha, West Bengal and interior areas of North-West hills. It is one of the cheapest leafy vegetables in tropical and sub-tropical parts of the country.

## 2. Crop improvement

### 2.1. Breeding objectives

The essential breeding objectives in vegetable amaranthus are Heat tolerance, Breeding for low anti-nutrient factors – low oxalate and low nitrate lines, improved seedling establishment, resistance to diseases, insects and tolerant to drought.

### 2.2. Breeding approaches

#### 2.2.1. Genetic variability

According to Faruk *et al.* (2009) and Kaiser *et al.* (2011) evaluation of genetic variability among accessions of a species is the first step to plan a breeding programme. This enables plant breeders to select the accessions or the particular plant trait to incorporate in a breeding programme.

The phenotypic co-efficient of variability were higher than genotypic coefficients of variability for all the traits studied. The genotypes 84-20 and A104 were found to be better for yield and yield parameters. The PCV and GCV were maximum for leaf stem ratio, number of leaves and fresh weight of leaves whereas it was minimum for stem girth. Heritability in broad sense was high for most of the traits studied but genetic advance was high for green yield per plant (61.07 %) and other yield parameters. The lowest genetic advance was noticed for total chlorophyll content (Revanappa and Madalgeri, 1997). Leaves per plant, diameter of stem base, fibre content and leaf area had significantly positive correlation with foliage yield. Inconsequential genotypic correlation was reported in nutrient and anti-oxidant content with foliage yield (Sarker *et al.*, 2014).

High heritability was observed in stem length (95.50 %), weight of dry leaf, weight of fresh and dry inflorescent was low heritable (47.70 %). A strong positive correlation of stem length, stem girth, number of inflorescent, inflorescent length and width with plant height and positive correlation with number of leaves, leaf width and number of branches with plant height were observed (Ogechi *et al.*, 2017). High magnitude of genotypic as well as phenotypic coefficient of variations were recorded for characters dry stem, dry plant weight, harvest index, leaf stem ratio and fresh stem weight suggested the considerable improvement on amaranth through selection for these traits. High heritability coupled with high genetic advance was observed for dry stem weight, dry plant weight, leaf stem ratio, fresh stem weight, dry leaf weight, harvest index, leaf area, plant fresh weight, fresh leaf weight indicating that the heritability is due to additive gene effects and selection may be effective (Asati and Chandrakar, 2017)

Presence of minimum difference between phenotypic coefficient of variation (PCV) and genotypic co-efficient of variation (GCV) for all the characters indicated that the phenotypes were true to the genotypes. Expression of high to moderate PCV and GCV for characters like number of inflorescence per plant, leaf: stem ratio, stem weight, yield per plant, leaf weight and plant height indicated the presence of good amount of variability among the materials evaluated. So selection for such characters would be effective in amaranthus. High heritability (>80 %) was observed for eight characters such as leaf: stem ratio, stem weight, number of inflorescence per plant, number of leaves per plant, yield per plant, petiole length, plant height and leaf weight. Moderate to high heritability (60-80 %) was observed for rest of the five characters. Highest genetic advance as percentage of mean was observed in number of inflorescence per plant followed by leaf: stem ratio, stem weight, yield per plant and leaf weight. Rest of the characters showed low to moderate values for this genetic parameter (Panda *et al.*, 2017).

In the experiment of identification of high yielding genotypes of amaranthus with good quality and tolerance to water stress and their genetic variabilty, the study revealed that, genotype Madhur Local was superior in yield (125.926 g plant$^{-1}$) performance under water stress condition. The character of vitamin A content registered the highest GCV (41.22 %) and PCV (41.25 %). High heritability coupled with high genetic advance was observed for leaf width, number of branches, yield plant$^{-1}$, protein content, fibre content and vitamin A (Shahiba *et al.*, 2020). The estimates of phenotypic co-efficient of variation were higher than the genotypic co-efficient of variation with narrow differences. The high estimates of heritability coupled with higher values of genetic advance as per cent mean were observed for all the parameters indicating pre-dominance of additive gene action and amenability for phenotypic selection in early generations. Total yield per plot was significantly correlated with number of branches per plot, stem weight of plant per plot and foliage yield per plant. High positive direct effect was observed between foliage yield per plot with stem girth, number of branches per plant, leaf length, stem weight of plant per plot, which are important characters to be accounted for gaining improvement in yield (Agadi *et al.*, 2019).

High heritability along with high estimates of genetic gain was estimated for fresh leaf yield per plant and seed yield per plant, which indicated the pre-dominance of additive variance in the expression of characters. Fresh leaf yield per plant was significantly and positively correlated with leaf length, leaf breadth, leaf area, petiole length and number of nodes at first cutting. In seed crop, seed yield per plant had positive and significant association with number of branches per plant and plant height. Path analysis revealed that leaf area, number of leaves per plant, number of nodes at first cutting and petiole length had maximum positive direct effect on fresh leaf yield per plant, whereas number of branches per plant, plant height and days to 50 % flowering had maximum positive direct effect on seed yield per plant (Harish kumar, 2020)

### 2.2.2. Characterization

Characterization and evaluation of genetic resources can provide breeders with valuable information for effective utilization of genetic resources for improvement of the programme as per the breeding objectives. Collection and evaluation of germplasm including wild types, wild relatives, local landraces, absolute varieties etc. offer ample scope to identify suitable types for a particular region (Shah *et al.*, 2018).

Wide range of variations were observed for most of the morphological parameters in *Amranthus spp.* under Jammu & Kashmir conditions. Most of the genotypes exhibited good early plant vigour with a few exceptions, exhibiting very good and poor early plant vigour. Erect growth habit was dominant in the germplasm with a few showing spreading growth habits. Leaf colour exhibited a wide range of variations with green and red as predominant classes. Green and red were the prominent classes for inflorescence colour, however, pink, yellowish green and reddish green colours were also noticed. Genotypes exhibited four classes with respect to stem colour *viz.*, red, yellowish green, pink and reddish green (Shah *et al.*, 2018). Results on characterization of vegetable amaranthus indicated dominance of 48.00 % as green leaf colour followed by yellowish green colour (18.00 %) while, dominance of 56.00 % as light green stem colour followed by 12.00 % as purple stem colour. Similarly, out of thirteen types of petiole coloured observed in the germplasm, light green colour was dominated (56.00 %) followed by green colour (12.00 %). On the other hand, out of five different types of leaf shape, the population was dominated by ovate and broad ovate shaped leaves (34.00 % each) followed by elliptic shaped (22.00 %). The evaluated vegetable amaranthus germplasm also showed 40.00 % as multi-cut type while 60.00 % as non-multi-cut types of genotypes (Ray, 2019).

Significant differences were observed for the traits like diameter of the bush, the length of the panicle, as well as the number of main branches inamaranthus. The genotypes had different types of the inflorescences, thus 9.10 % were semi-drooping, completely drooping 36.50 % and straight inflorescences 54.40%. The colour of the inflorescence also had variations from light green to dark pink (Gherase *et al.,* 2020). Study on molecular characterization of ten amaranthus genotypes using ten SSR primers and shown that out of 10 SSR primers used, only two were able to produce prominent PCR products. The binary data observed from the polymorphic primers through Computing Dice Similarity, indicated highest similarity index (0.77) existing between G3 and G4 genotypes whereas the lowest (0.14) in G1 and G6 genotype (Reddy, 2020). The results on morphological characterization of vegetable amaranthus germplasm showed dominance of short plant height (100.00 %) with upright growth habit (90.00 %) having pink stem (43.33 %), purplish red petiole colour pigmentation (43.33 %), ovate leaf shape (66.67 %), green colour leaves (53.33 %) without any blotch in leaves (83.33 %). These findings will be utilized towards development of new superior genotypes in vegetable amaranthus improvement programme (Suravi, 2021).

### 2.2.3. Evaluation

The germplasm collected is evaluated to identify the genotypes with desirable characters, cross-pollinated species of amaranthus exhibits ample genetic variability. Hence, it offers a considerable scope to identify suitable type for any particular region through evaluation

In an evaluation, among the genotypes IC 35463 recorded higher plant height, more number of leaves total drymatter production and highest grain yield (8.25 g/ha). It was on par with IC 420005 and IC 21930 ( Koppa *et al.*, 1997).

Among 32 accessions of *Amaranthus dubius* Mart. ex. Thell results shown that the accession, AD-23 had highest yield (382.00 g plant$^{-1}$) which was closely followed by AD-13 and AD-18 (Celini *et al.,* 2011). Estimation of 17 cultivars of amaranthus having four improved varieties and 13 local types and observed a vast range of variations for yield (55.80 to 303.90 q ha$^{-1}$). Among the cultivars, Bankura collection-3 (303.90 q ha$^{-1}$) and Bolpur collection-1 (287.00 q ha$^{-1}$) produced highest yield followed by Pusa Kirti (283.50 q ha$^{-1}$) (Mandal *et al.* 2012). While evaluating

27 genotypes including 25 germplasm lines and two checks of amaranthus (*Amaranthus tricolor* L.) observed highly significant differences among the genotypes for 19 traits under study. Taking into account the mean performance of the genotypes, five genotypes *viz*., IC-522214, IC-536718, IC-536712, IC-536699 and IC-536728 were identified as promising genotypes under Hyderabad situations (Tejaswini *et al.*, 2017)

The study on genotype evaluation for genetic variation in yield and yield attributing traits reveals that, genotypes exhibited highly significant variation for herbage yield and yield attributing traits. The variation studied indicated that the genotype KVA-28 (multicut type) was better performing for the traits leaf length (12.19 cm), leaf width (8.16 cm), leaf area (64.63 cm$^2$) and fresh leaf weight plant$^{-1}$ (11.55 g) during the kharif 2019. Similarly, in pooled analysis maximum leaf length was observed in KVA-24 (8.96 cm) followed by Konkan Durangi, Renushree and KVA-28; Highest leaf width was counted in a check variety CO-1 (6.56 cm); maximum leaf area was recorded in genotype KVA-28 (37.55 cm$^2$) followed by KVA-17, CO-1 (Check var). The genotypes *viz*., CO-1, Nisco Red, Arka Suguna, KVA-34, Arun found to be most promising for leaf: stem ratio during kharif 2019 and pooled analysis. The genotypes viz., CO-1 and Arka Suguna, KVA-18, Nisco Red, Pusa Kiran, Pusa Lal Chauli, KVA-34 and KVA-1 found to be the best for herbage yield during *kharif* (2019 and 2020) and summer (2020) season compared to *rabi* (2019-20) season. Hence, these genotypes were used as potential sources in breeding programme for multi-trait improvement (Basavaraj *et al.*, 2022).

### 2.2.4. Selection

In genetics, discrimination among individuals in the number of off-spring contributing to the next generation is known as selection. It is the generally followed breeding method in amaranthus. Many released genotypes are developed through this breeding method.

Considering the three genetic parameters together such as genotypic coefficient of variation (GCV), heritability estimates and genetic advance as percentage of mean altogether, it may be inferred that phenotypic selection for number of inflorescence per plant, leaf: stem ratio, stem weight, yield per plant, leaf weight and plant height may prove to be effective criteria for selection in amaranthus since, these characters are due to additive gene effects and are less influenced by the environment (Panda *et al.*, 2017).

**Table 1. Genotypes released through selection**

| Sl. No. | Genotype | Pedigree/Group | Year of release | Institute |
|---|---|---|---|---|
| 01. | Pusa Kirti | *A. tricolor* | 1991 | IARI, New Delhi |
| 02. | Pusa Lal Chaulai | *A. tricolor* | 1991 | |
| 03. | Arka Arunima | Acc. No. 18384 | _ | IIHR, Bangalore |
| 04. | Arka Suguna | IIHR 13560 | 2014 | |
| 06. | Arka Varna | *A. tricolor* | 2019 | |
| 07. | Co-1 | Tirunelvi local type | 1968 | TNAU, Coimbatore |
| 08. | Co-2 | Tanjavur local type | 1976 | |
| 09. | Co-3 | Local type (A. dubius) | 1981 | |
| 10. | Co-5 | A 166-1 | 1998 | |
| 11. | Arun | Palapoor local | 1992 | KAU, Thrissur |
| 12. | Renusree | *A. tricolor* | 2006 | |

(Muthukumar and Selvakumar, 2017)

### 2.2.5. Hybridization

The production of a hybrid by crossing two individuals of different genetical constitution is known as hybridization. It is an important method of combining characters of different parents.

The study on the evaluation of success rate of three different crossing methods (open pollination, hot water emasculation and hand emasculation) in three species of amaranthus revealed that hand emasculation has the highest success rate 74 % (Markus *et al.*, 2016)

- **Pusa kiran:** Developed through hybridization between *A. tricolor* x *A. tristis* at IARI, New Delhi and released in the year 1991.

#### 2.2.6. Mutation

Many *Amaranthus* species are highly self pollinated, limiting variability within accessions. Spontaneous genetic variation is low in these amaranthus indicating the potential to obtain useful variability with induced mutant techniques. Mutants with basal branching habit could be economic value for vegetable production because the higher number of branches could increase leaf harvests, especially with improved regrowth ability. The viable mutation frequency increased (2-8 %) when the irradiation doses were increased (3-15 KR) for six amaranthus genotypes tested, with the high doses yielding more early, and the lower doses more late maturing mutants. Earliness could be advantageous for grain amaranths to escape drought and fit into crop rotations (Hari Har Ram, 2012).

## 3. Production technology

### 3.1. Soil type and germination

The study on germination response of the plant to environmental conditions and variation in its germination characteristics at various depths in different soil types shows that, the highest germination was recorded at 25 °C and under continuous dark conditions, although the seeds germinated well under a wide range of temperatures and other photoperiods. The species germinated under all seeding depths considered, though late emergence was observed at depths below 2 cm. In addition, a significant ($P < 0.05$) interaction in pattern of germination was observed in three out of the five soil types tested, whereas the control (unfractionated) soil showed a highly significant ($P < 0.01$) interaction with the silt clay loam and loam soil. This overlapping interaction further confirmed that the plant has wide surviving capabilities in various soils and environmental conditions, hence, for optimum seedling emergence, it is recommended that *A. caudatus* be planted in a loamy soil maintained at 25 °C in a continuous dark environment (Jimoh *et al.*, 2019)

### 3.2. Spacing

Experimental results of the effect of planting density and nutrient management in amaranthus (*Amaranthus tricolor* L.) cv. Arka Suguna reveales that *Amaranthus* cv. Arka Suguna responded well to plant densities as well as nutrient combinations. Higher plant density (3,33,333 plants ha$^{1}$) and soil application of 25% recommended dose of fertilizers as basal application along with 2% foliar spray of 20-20-20 mixture produced higher yield per hectare (24.66 t/ha) and economic returns. (Durgaprasad, 2012)

### 3.3. Nutrient management

The study on effect of different level of farmyard manures (0 t/ha, 15 t/ha, 25 t/ha and 35 t/ha) on the growth and yield of *Amaranthus cruentus* , shows that all parameters measured increased with plant age and significant differences ($P > 0.05$) were observed among the farmyard manure levels. Addition of more manure to the seedlings had positive effect on all the parameters measured. The seedlings treated with manure level of 35 t/ha had the highest mean values of 123.27 cm, 11.585 cm$^2$, 141.56, 1.75 kg and 0.99 kg per plant for plant height, leaf area, number of leaves, fresh and dry weights respectively while those treated with manure at 0 t/ha had the least values for the parameters measured. In rainforest agro-ecological zones with heavy rainfall that encourages the decomposition of poultry manures. The application of manure level of 35 t/ha to amaranthus seem to had the highest mean values for all the parameters measured such as plant height, leaf area, number of leaves, leaf area, fresh and dry weights (Akparobi, 2009). Organically and conventionally grown amaranthus were analysed for their nutrient composition. Poultry manure application to amaranthus resulted in significant increase in iron and calcium contents in the edible part of leaves. Application of vermicompost to the crop significantly increased in vitro iron availability, total carotenes, crude fibre, vitamin C and zinc contents compared to conventionally grown crop. Both conventionally and organically grown crops were found to contain significantly higher nitrates. Among the organic manures, vermicompost and poultry manure application to amaranthus resulted in significantly higher nitrates. Application of organic manures was found to be significantly influence the nutrient content of these crops compared to conventional fertilizers. (Shankar *et al.*, 2013).

The application of different level of nitrogen fertilizer significantly influenced the plant height, Number of leaves, leaf length, leaf width, stem diameter leaf area and yield. The linear increase in the total green yield of amaranthus was evident with every increase in dose of nitrogen. Plant height, leaf length, leaf width, leaf area and fresh weight increased with increase in N application. Highest vegetables yield were obtained at 140 kg nitrogen per hectare with a mean yield of 187.90 quintal per hectare which is statistically different to the control and other treatments except treatment 100 kg nitrogen per hectare. (Dehariya *et al.*, 2019).

### 3.4. Integrated pest management

The study conducted on insect defoliators of amaranthus, fenugreek and palak revealed that 42 insect species on amaranthus and 37 on fenugreek and palak which belonged to Lepidoptera, Coleoptera, Orthroptera, Hemiptera and Hymenoptera, out of which 27 were new records on amaranthus and 35 species on fenugreek and palak. Among them 14 species of lepidopterous insects, four species of grasshoppers, six species of coleopterous insects, four species of bugs and a tenthredenid were phytophagous species, while four species of lady bird beetles, three species of preying mantids, a dragon fly, a potter wasp and a tettigonid insect were the natural enemies. Higher leaf yields were recorded on all three leafy vegetables when protected against defoliators (*Agrotis segetum* (Denis and Schiffermuller) and Hymenia recurvalis (Fabricius)) by insecticide treatment plot and net protection. The least foliage damage was noticed in the insecticide treated plot followed by net protected plot and maximum foliage damage was noticed in the untreated plot. Among the insecticides evaluated against *A. segetum* and *H. recurvalis* on three leafy vegetables, Fipronil 5 SC @ 1 ml/l, Emamectin benzote 5 SG @ 0.25 g/l and Indoxacarb 15.8 EC 0.25 ml/l were significantly superior over untreated control with respect to reducing larval population and the per cent foliage damage. Azadirachtin also performed well against the defoliators. Treatment with Emamectin benzoate, Indoxacarb and Fipronil produced significantly higher leaf yields, respectively 21.67, 21.44 and 20.67 tonnes $ha^{-1}$ in amaranthus, 14.14, 15.42 and 14.57 tonnes $ha^{-1}$ in fenugreek and 15.00, 15.10, and 15.33 tonnes $ha^{-1}$ in palak. Emamectin benzoate, Indoxacarb and Fipronil proved to be most profitable treatments by fetching higher net returns. However higher Incremental cost benefit ratio (ICBR) was obtained in Malathion and Dichlorvas (Manjula, 2014).

The study of diversity of insects associated with amaranthus shows that, total of thirty one insects belonging to twenty one families and eight orders; comprising of twenty six insect pests, four predators and one parasitoid were recorded. Each genus recorded during the study was represented by a single species totaling thirty one genus and species. Order Hemiptera was the most diverse with a relative abundance of 29.03 per cent followed by Coleoptera (22.58 %), Lepidoptera and Thysanoptera (12.90 %), Homoptera, Orthoptera and Hymenoptera (6.45 %) while Neuroptera was the least (3.23 %) abundant. (Thara *e tal.*, 2019).

## 4. Post harvest management

The study on effect of maturity (10, 20 and 30 days after planting (DAP), leaf position (apex, middle and base) and postharvest storage (24, 48 or 72 h in the refrigerator, covered with a wet cloth, placed in a polyethylene bag, or the roots put in water) on the nutrient composition and organoleptic quality of leaves shown that, Ca, Fe and ascorbic acid contents were significantly higher at 20 DAP. Leaf protein content was unaffected by any of the treatments. In both seasons, the green cultivar was more nutritious than the red one. The red cultivar, however, when grown in the summer season, had the better organoleptic quality. Leaves were best stored in the refrigerator for no longer than 24 h, otherwise the ascorbic acid content was significantly reduced (Jijiamma, and Prema, 1993).

In the study on dehydration of amaranthus leaves and its quality evaluation, the leaves were subjected to pretreatments *viz*., blanching, sulphitation, blanching + sulphitation prior to drying under cabinet drier and microwave oven drier. Samples dried without any pretreatments served as control. Results indicated that blanched amaranthus leaves dried at 60 °C for 2 h 37 min in cabinet drier and 3 min 31 sec in microwave oven at 900 power density were found to be better with respect to yield (12.55 & 13.73 % respectively), moisture (3.72 & 3.32 % respectively), physiological loss in weight (87.44 & 86.27 % respectively) and rehydration ratio (4.30 & 4.23 respectively) compared to other pre treatments imposed before drying. Blanched cabinet dried leaves registered higher moisture (3.72 %), protein (18.34 %), ash (18.64 %), iron (56.21 %) and copper (0.50 %) while unblanched leaves had higher calcium and zinc contents (296.14 and 11.06 mg/100 g respectively). On the other hand, unblanched microwave dried leaves recorded higher protein (21.87 %), ash (17.98 %), calcium (293.92 mg/100 g), iron (26.23 %), zinc (8.88 %) and copper (0.63 %) while blanched microwave dried leaves had higher moisture content of 3.32 per cent. Chlorophyll content (mg/100 g) decreased from 181.5 (fresh) to 92.81 and 52.90 on drying and 48.86 and 48.62 on storage (cabinet and microwave dried leaves respectively). Dehydrated leaves could be stored up to six months under ambient condition without considerable changes in the moisture and rehydration ratio. Unblanched amaranthus is most acceptable with regard to flavor and taste and households are willing to purchase if available in the market (Rajeshwari *et al.*, 2013).

When rajagira leaves with tender stem were packed in polypropylene 150 gauge with vents the shelf life was extended upto six days with 84.36 % retention of moisture, 21.01 % physiological loss in weight and 9.01 % decaying, while polypropylene 100 gauge pouches extended shelf life upto four days with 86.32 % moisture retention, 1.27 % physiological loss in weight, 16.98 and 14.52 % yellowing and decaying, respectively (Reddy *et al.*, 2013). In the experiment on dehydration to know the best drying method for amaranthus leaves and preparation of RTS soup mix from dried leaves. The results indicated that Microwave vacuum drying for 60s on-off was found to be best treatment for drying of amaranthus leaves having 3.60 % moisture content, 3.21% fat, 19.75 % protien, 19.04 % ash, 1.77 mg/100 gm ascorbic acid, 14.01 % fiber, 43.85 % carbohydrate. Soup mix powder of (15:45 = amaranthus leaves powder: arrowroot starch powder) showed best results for nutritional analysis i.e. 14.43% protein content, 60.96 % carbohydrate content, 1.29 % fat content, 7.54 % fiber content, 4.10 % ash content, 2.53 mg/100 g ascorbic acid at 19.76 % moisture content, and 313.83 cal/100 g energy (Peje, 2019).

**5. Conclusion**

Amaranthus is a versatile crop with a long history of domestication and use. To date only a modest amount of research related to crop improvement and production technology has been done with this plant, mostly with the grain types. Research works need to be conducted with the aim of reducing anti-nutritional compounds *viz*., oxalates and nitrates in leaves. It is an important plant to diverse human populations around the world, but its use could be significantly enhanced through further breeding and research. With the diverse collection of germplasm available, rapid progress could be made with a minor investment in screening and breeding projects. The studies on improvement of cultivation practices may help the farmers to get higher economic returns. Investigations by amaranth researchers and farmers around the world have provided a solid foundation for further improvement of this precious plant.

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