QUALITY EVALUATION IN ORGANIC AMARANTHUS (*Amaranthus tricolor* L.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)"** is a record of research work done independently by **Ms. APARNA, T.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ABBREVIATIONS

A.O.A.C.	- Association of Official Analytical Chemists
g	- Gram
mg	- Milligram
m	- Metre
ml	- Millilitre
cm	- Centimetre
µg	- Microgram
º C	- Degree centigrade
%	- Per cent
t	- Tonnes
ha	- Hectare
nm	- Nanometre
kg	- Kilogram

Introduction

1. INTRODUCTION

Amaranthus, a cosmopolitan genus of herb belonging to the family *Amaranthaceae*, is the commercially grown leafy vegetable in Kerala (F.I.B. 2005). This crop is an attractive option for farmers because of its very short duration, high productivity, drought tolerance and relatively low incidence of pests and diseases. It is often referred as poor man's spinach as it is a rich source of protective nutrients like vitamins and minerals. Though, highly esteemed as a nutritious vegetable, the presence of antinutrients like oxalates and nitrates hinder its large-scale consumption (Marderosian *et al*., 1979).

Organic food is derived from crops or animals produced in a farming system that avoids the use of man-made fertilisers, pesticides, growth regulators and livestock feed additives (Institute of Food Science and Technology, 1999). Organic food production can be defined as an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity (Winter and Davis, 2006). Organic foods are emerging as a global trend among health conscious consumers in developed and developing nations due to the perception that they have superior sensory attributes, contain lower levels of pesticides and synthetic fertilisers and higher levels of nutrients and protective phytochemicals.

Organic foods are readily acceptable by the consumers as they are considered to be free from harmful chemicals and contain higher nutritional levels compared to conventional products (Maity *et al*., 2010). They contain higher minerals and vitamins (Worthington, 1998) antioxidants (Woese *et al*., 1997; Weibel *et al*., 2000; Heaton, 2001; Asami *et al*., 2003; Chassy *et al*., 2006) and have better flavour (Weibel *et al*., 2000; Reganold *et al*., 2001) than crops produced using conventional methods. Due to these advantages the demand for organically grown foods is on the rise.

Organic agricultural systems have proved to produce food with high quality standards. Organic vegetables are usually considered by the consumer to be more nutritious and safer than conventionally grown vegetables. Vegetables being rich in nutrients, occupy a prominent position among foods and a distinct place in the balanced diet of individuals. However, various studies have indicated inconsistent results in the quality aspects of organic crops especially with respect to nutritive value, acceptability and productivity when compared to conventional crops. As consumer interest in organically grown vegetables is increasing there is a need to answer whether the vegetables are more nutritious than those cultivated inorganically.

Hence, a preliminary study entitled 'Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)' was undertaken with the objective of evaluating the effect of organic farming system on the yield, physico-chemical characteristics and organoleptic qualities of amaranthus.

Review of literature

2. REVIEW OF LITERATURE

Literature relevant to the study entitled "Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)" is reviewed in this chapter under the following sub headings.

2.1. Importance of organic farming

2.2. Importance of green leafy vegetables in our diet

2.3. Qualities of organically grown foods

2.1. Importance of organic farming

According to Funtilana (1990), Organic farming is giving back to the nature what is taken from it. Organic farming has been defined by Lampkin (1990) as a production system which avoids or largely excludes the use of synthetically compounded fertilisers, growth regulators and livestock feed additives. Organic farming is the form of agriculture that relies on crop rotation, green manure, compost, biological pest control etc to maintain the soil productivity excluding or strictly limiting the use of synthetic fertilisers and synthetic pesticides, plant growth regulators, livestock feed additives and genetically modified organisms (Lotter, 2003).

Knorr and Vogtmann (1983) observed almost same yield in crops grown under conventional and organic systems. Srivastava (1985) observed that the application of organic manures resulted in increased organic carbon content, total nitrogen, available phosphorus and potassium status of soil. However, Alvarez *et al*. (1988) indicated more or less similar availability of the nutrients from the soil under both cultivation systems due to the application of organic manures.

Loganathan (1990) observed improved soil physical characteristics like infiltration rate, total porosity and hydraulic conductivity of red soil due to the application of organic amendments like saw dust, ground nut, shell powder, coir dust and farm yard manure, each at 2.5 and 5t ha^{-1}. Kale *et al*. (1991) indicated the use of organic manures like farm yard manure, vermicompost, neemcake for improving the productivity of crops, maintaining soil fertility and positive influence on soil texture and water holding capacity.

Importance of organic farming in protecting the long-term fertility of soil by maintaining organic matter level, soil biological activity, careful mechanical intervention and nitrogen self sufficiency through the use of legumes and biological nitrogen fixation as well as effective recycling of organic materials including crop residues and livestock wastes was indicated by Padel and Lampkin (1994).

More (1994) reported the importance of adding farm wastes and organic manures in increasing the status of available nitrogen and available phosphorus of the soil. Banerjee (1998) reported that organic manures which had almost all nutrient elements required for plant growth are capable of improving soil aeration, permeability, aggregation, water and nutrient holding capacity of soil.

Rubina *et al*. (1999); Shankar (2000) and Ram and Rajput (2000) indicated the importance of organic agriculture in improving soil conservation, soil ecology and environment. Among different manures like poultry manure, vermicompost, neemcake and package of practices recommendations Sharu (2000) observed higher levels of soil nitrogen with application of poultry manure. Kumar and Surendran (2002) indicated the influence of vermicompost in improving the physical, chemical and biological properties and water holding capacity of soil.

Jolly *et al*. (1989) indicated that organic foods are better than conventional foods because of its safety, freshness, general health benefits, nutritional value, effect on environment and flavour. Lampkin (1990) stated that organic farming reduces the cost of production by utilization of organic wastes or its by-products against chemical fertilisers. Wandel and Bugge (1997) also stated that organic consumers identified health and environmental reasons for purchasing organic foods. Woodward and Meier-Ploeger (1999) stated that approximately 70 per cent of organic consumers cited health as the primary reason for purchasing organic food. Stolze *et al*. (2000) and Hansen *et al*. (2001)

indicated that organic farming sustains diverse ecosystems of plants, insects and animals as compared to conventional farming.

Baker *et al*. (2002) suggested that organic farming is more economical to the farmer than chemical farming as it saves the cost of external inputs and utilizes the inputs present in farm itself. Organic foods are a simple way to reduce the toxicity of pesticides and harmful additives and ensures high quality than conventional foods (Pandey, 2010).

2.2. Importance of green leafy vegetables in our diet

Green leafy vegetables are rich sources of micronutrients and phytochemicals having antioxidant properties which offer protection against heart diseases and certain types of cancer (Saxena, 1999). Leafy vegetables are the cheapest of all vegetables and are within the reach of poor man and being rich in nutrients, they are classified under protective foods (Srilakshmi, 2001). According to Rajeshwari and Subhulakshmi (2004) green leafy vegetables contain largest classes of phytonutrients.

India's flora comprises of 6000 species of plants used for consumption, $1/3^{rd}$ of which are green leafy vegetables. Green leafy vegetables are a source of minerals and vitamins when consumed regularly and they can substantially improve micronutrient status of the Indian population (Anuradha *et al*., 2007). Dark green leafy vegetables are the most concentrated source of nutrition when compared to other foods (Dolson *et al.,* 2008).

According to Peter (1979) and Nautiyal and Raman (1987) drumstick leaves are more nutritious than most of the commonly used vegetables. Studies conducted by Kowsalya and Mohandas (1999) indicated that cauliflower leaves are rich in macro and micronutrients.

Castanedac *et al*. (1986) reported almost similar protein content in amaranthus and spinach. High protein in colocasia leaves (Nayar, 1992) ceylon spinach (Saikia and Shadeque, 1994) and curry leaves (Pathak *et al*., 2000) were also observed. Green leafy vegetables are a good source of proteins and the drymatter of leaves contain as much protein as legumes (Reddy, 1999).

Green leafy vegetables are rich in provitamin A, which keeps the eyes and skin in a healthy condition (Menon, 1980; Swaminathan, 1987). Inclusion of 30-50 g green leafy vegetables like amaranth in the daily diet can meet the daily requirement of vitamin A (Gopalan *et al*., 1989 and Reddy, 1999).

Leafy vegetables such as spinach, amaranth, lettuce, celery, cauliflower, mint and coriander are rich sources of beta carotene, lutein, zeaxanthin and betacryptoxanthin (Devadas and Saroja, 1980; Kowsalya and Mohandas, 1999; Mathew, 2000; Singh *et al*., 2001; Craig, 2003 and Kumaran, 2003).

The commonly consumed green leafy vegetables in India such as spinach, amaranth, fenugreek, mustard, drumstick, mint, radish leaves, coriander leaves, curry leaves etc are rich and inexpensive sources of beta carotene (Bressani *et al*., 1986; Gopalan *et al*., 1989; NIN, 1993).

Leafy vegetables contain considerably more carotenoids than tuberous vegetables and fruits and are mainly deposited in the leaves, which have higher relative beta carotene content than stalks (Speek and Schreuss, 1988). Singh *et al*. (2001) reported that available beta carotene from greens in India is 95 per cent and out of this 90 per cent is contributed by green leafy vegetables.

High vitamin C in leaves of spinach, amaranth, fenugreek, mustard, drumstick, mint, coriander leaves (Sreeramulu *et al*., 1983; Thimmayamma and Pasricha, 1996) tender stems of amaranth (Varalakshmi *et al*., 1998) and cauliflower (Kowsalya and Mohandas, 1999) were also observed. Gillman (1995) stated that green leafy vegetables are rich in antioxidant vitamins like vitamin C, vitamin A and vitamin E.

Green leafy vegetables are rich in vitamin C, which is required to keep the gums in a healthy condition (Menon, 1980; Gopalan *et al*., 1989). Rimm *et al*. (1993) reported that consumption of fruits and vegetables, particularly green leafy vegetables have a protective effect against coronary heart disease. Studies conducted by Swaminathan (1987); Mathew (2000); Singh *et al*. (2001); Craig (2003); Kumaran (2003) and Dolson *et al*. (2008) reported that green leafy vegetables are rich in vitamin C.

Booth *et al*. (1995) reported that green leafy vegetables like collard and kale are good sources of phylloquinone (vitamin K_1), which is an important nutrient involved in the regulation of blood coagulation. High folic acid in green leafy vegetables was reported by Craig (2003) and Swaminathan (1987). Dolson *et al.* (2008) found that dark green leafy vegetables are rich sources of vitamins including vitamins K, E and many of the B vitamins.

Studies conducted by Philip *et al*. (1981); Gopalan (1982); Swaminathan (1987); Gillman (1995); Mathew (2000); Craig (2003); Joshipura (2003); Kumaran (2003) and Dolson *et al*. (2008) found that green leafy vegetables are rich in calcium, iron, phosphorus, magnesium, sodium, potassium, copper, iodine, sulphur and boron.

Gopalan (1982) found that drumstick leaves are rich in calcium, phosphorus, iron and trace minerals like copper and iodine. According to Imungi and Potter (1983) cowpea leaves are rich in minerals like iron, calcium, phosphorus and zinc.

A study conducted by Gupta and Wagle (1988) found that leaves of chickpea had the highest amount of iron, copper, manganese and calcium, while mustard leaves had the highest amount of phosphorus. Spinach, on the other hand had the lowest content of copper, calcium and phosphorus and the highest content of zinc and sodium compared to other vegetables. The leafy vegetables consumed by the Naga tribes of Nagaland and Manipur (NIN, 1988) were found to be rich in calcium, magnesium, iron and zinc.

Nayar (1992) reported that colocasia leaves are superior to that of cabbage and reported high minerals in them. Shingade *et al*. (1995) reported that *Amaranthus tricolor* is comparatively high in phosphorus, potassium, calcium, magnesium and micronutrients like iron and boron.

Gins *et al.* (2001) analysed the leaves of *Amaranthus tricolor*, *Chrysanthemum coronarium, Nasturtium officinale* and *Lepidium meyenii* and reported considerable amounts of minerals like potassium, iron, calcium and phosphorus. Hohl *et al*. (2001) observed high magnesium content in lettuce. Singh *et al.* (2001) observed high iron content in spinach, mint, amaranth, cauliflower and coriander leaves.

The carotenoid content of several dark green vegetables is found to be associated with a lower risk of various epithelial cancers (Reddy, 1999). Lutein, zeaxanthin and carotenoids found in dark-green leafy vegetables, are concentrated in the eye lens and muscular region of the retina, and play a protective role in the eye, reduce the risk of breast and lung cancers and may contribute to the prevention of heart disease and stroke (Ascherio, 2003).

Green leafy vegetables rich in beta carotene, the precursor of vitamin A improve immune function (Joshipura, 2003). Dolson *et al.* (2008) reported that beta carotene, lutein and zeaxanthin present in green leafy vegetables protect cells from damage and eyes from age-related problems.

Hohl *et al*. (2001) found that head lettuce contain glycosides which are largely concentrated on the outer leaves and have antioxidative activity.

Hunter and Fletcher (2002) reported that green leafy vegetables have a high concentration of antioxidant components. But, Yadav and Sehgal (1995) and Chu *et al.* (2000) observed losses of antioxidant components from green leafy vegetables during cooking.

Cabbage, cauliflower and broccoli have powerful antioxidants and are rich in indoles and isothiocyanates which protect against colon and other cancers (Ascherio, 2003). Lettuce is an important source of antioxidant compounds which offer health benefits against chronic diseases such as cancer (Nicolle *et al*., 2004; Llorach *et al*., 2008).

Despite high level of nutrients, the main constraint to the nutritive value of green leafy vegetables is the presence of some antinutritional factors like oxalates and nitrates (Sadik, 1971; Singh and Saxena, 1972). High nitrate in leafy vegetables such as spinach, lettuce and celery was reported by Maynard *et al*. (1976).

Generally, vegetables are the largest source of dietary nitrate and formed by endogenous synthesis in the human intestine (Tannenbaum *et al*., 1978). Reddy (1999) found that certain green leafy vegetables such as spinach, amaranth and gogu are rich in oxalic acid and hence individuals prone to renal calculi should avoid such foods.

Gillman (1995) indicated reduced risk of cardiovascular diseases and stroke in people who consumed green leafy vegetables. According to Manay and Shadaksharaswamy (1995) drumstick leaves are considered useful in scurvy and catarrhal affliction.

Apart from minerals and vitamins, medicinal properties of green leafy vegetables like anti-histaminic (Yamamura *et al*., 1998) anti-carcinogenic (Kumar *et al.*, 2002; Ascherio, 2003; Craig, 2003) hypolipidemic (Khanna *et al*., 2002) anti-bacterial (Kubo *et al*., 2004) and anti-diabetic activity (Kesari *et al*., 2005) were also reported.

The high magnesium content in lettuce was found to be good for the brain, nerves and muscular tissues (Hohl *et al*., 2001). Craig (2003) observed high magnesium content and low glycemic index in green leafy vegetables, which is good for persons with type 2 diabetes. Chandrashekar (2003) indicated that moringa leaves are good for reducing premature ageing and for protection against functional sterility in men and women.

2.3. Qualities of organically grown foods

Anez and Tavira (1984) observed higher yield in lettuce when poultry manure was applied. Subhan (1987) also reported increased yield in tomato when compost maize straw, sheep manure and composted rice straw were applied. Lu and Bai (1989) also reported increased yield in cauliflower by the application of processed chicken manure.

Bohec (1990) noted maximum yield in celery, lettuce and leek by the application of farm yard manure, composted urban waste or composted sewage-sludge, when compared to those grown without added organic matter. On the other hand Lampkin (1990) observed 24 per cent lower yield for organic produce compared with conventionally grown produce.

Gardini *et al.* (1992) studied the effect of poultry manure and mineral fertilisers on the yield of crops and found highest yield in spinach by the use of poultry manure. Hernandez *et al*. (1992) found significantly greater yield in lettuce which were grown with fresh sewage sludge and composted wastes. Kropiz (1992) also observed highest average yield in cabbage by the application of farm yard manure.

According to Anitha and Prema (2003) the yield effects were significant due to the application of vermicompost on amaranthus when compared to those grown without added organic matter. A study conducted by Preetha (2003) revealed that amaranthus grown organically had significantly high yield per plot during the first and second harvest. Thankamony (2005) also indicated significantly high yield per plot in amaranthus grown organically.

Shekhar and Rajashree (2009) reported that the application of FYM @ 20 t ha^{-1} recorded the highest number of fruits per plant, fruit weight and yield in cowpea.

Application of vermicompost along with organic manures resulted in early flowering, increased fruit size, number of fruits and yield in tomato and chilli (Prabhu *et al*., 2010). Sangeetha and Ganesan (2010) reported beneficial effects on seed germination and yield in green gram by the application of organic inputs like cow dung, goat dung, poultry manure, leaf compost and farm yard manure.

Silva (1986) found that farm yard manure increased the head weight of cabbage. However, the author noted increased incidence of black rot in cabbage by the application of farm yard manure.

Organic products were reported to be safe with better taste and quality (Davies *et al*., 1995; Lakin and Shannon, 1999; Cunningham, 2001 and Makatouni, 2001).

Application of organic manures in the form of vermicompost in soil recorded the highest value for all the available nutrients (Rajalekshmi, 1996). Woese *et al*. (1997); Worthington (1998) and Tinker (2001) also reported higher nutrient content in organic produce than conventional produce. Studies conducted by Brandt and Molgaard (2001) and Tinker (2001) reported that organic produce contain more phytonutrients than non-organic produce.

Chattoo *et al*. (2009) observed significant influence of organic sources on nutrient uptake and reported that application of poultry manure resulted in highest uptake of all major nutrients in onion.

The moisture content in wheat grown organically and conventionally was found to be almost same (Shier *et al*., 1984). On the other hand Magkos *et al*. (2003) stated that organically grown crops have less moisture than conventionally grown crops.

Schupan (1974) observed higher concentration of proteins in organic vegetables. Wolfson and Shearer (1981); Dlouhy (1989) and Starling and Richards (1990) indicated higher levels of protein in conventionally grown wheat and maize when compared to organically grown. However, Shier *et al*. (1984) observed no significant variation in the protein content of organically or conventionally grown wheat.

Weibel *et al*. (1998) observed more protein in organically grown apples. But Worthington (2004) found low protein in organic crops. The protein content of amaranthus grown organically was found to be significantly high (Thankamony, 2005).

Woese *et al*. (1997) did not observe any significant difference in the B-vitamin and vitamin A levels of organically or conventionally grown cereals, potatoes and vegetables. However, Worthington (1998) observed high vitamin content in organically grown crops.

The beta carotene content of carrots grown under organic and conventional fertilisation was found to be almost same (Eggert and Kahrmann, 1984). However, Leclerc *et al*. (1991) and Rodriguez-Amaya (2003) observed high beta carotene in organically grown kale, carrots, potatoes and celeriac roots. Mercadante and Amayua (1991) and Rattler *et al*. (2005) also reported high beta carotene in kale and lettuce grown organically when compared to those grown using herbicides.

Tee *et al*. (1997) observed higher concentration of beta carotene in organically grown chinese mustard and swamp cabbage. Ismail and Fun (2003) found that organically grown swamp cabbage had the highest beta carotene, while organically grown chinese mustard, chinese kale, lettuce and spinach did not indicate any variation in the beta carotene content.

Leclerc *et al*. (1991) observed more thiamine in organically grown carrots, potatoes and celeriac roots.

Organically grown chinese mustard and swamp cabbage were significantly higher in riboflavin content (Tee *et al*., 1997). But Ismail and Fun (2003) did not indicate any difference in the riboflavin levels of organically and conventionally grown chinese mustard, kale, lettuce and spinach.

Studies conducted by Azevedo and Rodriguez-Amaya (2005) observed that conventionally grown kale have higher beta carotene and lutein in the mature leaves and violaxanthin was unusually high in the young leaves and neoxanthin was same at both stages of maturity. Higher levels of carotenoids in organic tomatoes was reported by Caris-Veyrat *et al*. (2005).

Schupan (1974) observed higher concentration of vitamin C in organic vegetables. Spinach and lettuce grown organically were found to be rich in ascorbic acid compared to those grown conventionally (Schupan, 1975). However, Thoroughgood and Hypchung (1976) did not observe any significant variation in the ascorbic acid content of potato, tomato and pepper grown using these two methods. Lairon *et al.* (1984) and Meier-Ploeger *et al.* (1989) also did not observe any variation in vitamin C content of kale, cabbage and lettuce grown organically and conventionally.

Lower content of ascorbic acid in organically grown spinach (Ahrens *et al*., 1983) swiss chard (Comis, 1989) kale (Hornick, 1989) and lettuce (Masamba and Nguyen, 2008) were also reported. Lampkin (1990) found higher vitamin C levels in organic vegetables associated with higher dry matter values.

High vitamin C in organically grown carrot and apples (Pither and Hall, 1990) carrots, potato and celeriac roots (Leclerc *et al*., 1991) chinese kale, lettuce and swamp cabbage (Tee *et al*., 1997; Ismail and Fun 2003) peaches (Carbonaro *et al*., 2002) and tomatoes (Caris-Veyrat *et al*., 2005) were also observed. However, Cayuela *et al*. (1997)

did not observe any difference in the vitamin C content of strawberries cultivated by these two methods.

Worthington (2004) indicated significantly high vitamin C in organic crops when compared to conventional crops. Zhao *et al*. (2006) and Rembialkowska (2007) reported that leafy vegetables produced under organic methods were rich in vitamin C.

Schupan (1974) observed higher concentration of calcium, potassium, iron, phosphorus and lower sodium in organic vegetables. Lazzati *et al*. (1975) observed that organic fertilization increased total root mineral content and leaf calcium in vegetable crops.

Pither and Hall (1990) found that apples and carrots grown organically were higher in potassium. Smith (1993) also revealed that organically grown apples contained high calcium, magnesium, iron, phosphorus, manganese, sodium and no difference in potassium, copper and zinc. Sagaya and Gunathilagaraj (1996) noticed more potassium and phosphorus in amaranthus grown with earthworm application.

The mineral constituents of organically grown and conventionally grown strawberries (Cayuela *et al*., 1997) cereals, potatoes or vegetables (Woese *et al*., 1997) were found to be almost same. However, Worthington (1998) found high mineral content in organically grown crops. The zinc content of organically and conventionally grown potatoes and carrots were found to be same (Jorhem and Slanina, 2000).

Organic vegetables like beans, tomatoes, capsicum, and silver beet have considerably higher mineral content than conventionally grown vegetables (ORGAA, 2000). Worthington (2004) found that organic crops contained 21.1 per cent more iron, 29.3 per cent more magnesium and 13.6 per cent more phosphorus than conventional crops.

Ungoed-Thomas (2007) found more minerals in organic cabbage and spinach. A study conducted by Masamba and Nguyen (2008) indicated higher calcium and potassium in organically grown lettuce.

The uptake of N, P and K and micronutrient in farm yard manure treatment was superior to all other commercial manuring in okra (Rakshit, 2009).

Barker (1975) did not observe any difference in the nitrate content of organically and conventionally grown spinach. But, high nitrate content in organic cabbage and spinach was reported by Ahrens *et al*. (1983) and Meier-Ploeger *et al.* (1989). The nitrate contents in lettuce, cabbage, beetroot, potato and carrot were found to be almost same in these two methods (Stopes *et al*., 1988).

Linder (1989) indicated 14.2 per cent nitrate in organically grown lettuce. Woese *et al.* (1997) found higher nitrate concentration in green leafy vegetables grown under conventional conditions. Worthington (2004) also observed more nitrate in conventionally grown crops. Rattler *et al*. (2005) indicated low levels of nitrate in organically grown lettuce.

Organically grown crops contain higher antioxidants (Woese *et al*., 1997; Weibel *et al*., 2000; Heaton 2001; Asami *et al*., 2003; Chassy *et al*., 2006). Mitchell (2007) indicated that organic tomatoes had excessive amounts of antioxidants like quercetin (79 per cent higher) and kaempferol (97 per cent higher) than conventionally grown crops.

Higher flavonoids in organically grown chinese cabbage, spinach (Goh and Vityakon, 1986; Ren *et al*., 2001) broccoli and green cabbage (Tarwadi and Agte, 2005) were reported. However, Mikkonen *et al*. (2001) reported no consistent differences in the flavonol levels in organically and conventionally grown black currants. Organic produce had more flavonoids, an important antioxidant (Dungan, 2007) than conventional produce.

The phenolic content of organically grown fruits likes apples (Weibel *et al*., 1998) peaches and pears (Carbonaro and Mattera, 2001) tomatoes (Caris-Veyrat *et al*., 2005) apple pulps (Veberic *et al*., 2005) were found to be high. However, organically grown strawberries and blueberries had no consistent effects on phenolics (Hakkinen and Torronen, 2000). Sweet pepper grown under organic culture was reported to have high levels of phenolic compounds (Francisco *et al*., 2008).

Young *et al*. (2004) indicated that although organic production method alone did not enhance biosynthesis of phytochemicals in lettuce and collards, the organic system provided an increased opportunity for insect attack, resulting in a higher level of total phenolic compounds.

Rattler *et al*. (2005) found lower levels of polyphenol in organically grown lettuce. Young *et al*. (2005) did not observe any difference in the phenolic levels of lettuce and collards grown in organic and conventional methods. However, the author indicated higher phenolics in organic pakchoi.

The polyphenoloxidase enzyme in organic and conventionally grown grapes did not show any variation but diphenolase activity was found to be two times higher in organic grapes than from conventional grapes (Nunez- Delicado *et al*., 2005). Zhao *et al.* (2007) indicated that organically grown lettuce is rich in phenolics. Higher content of polyamines and total phenols in organic vegetables were reported by Pereira-Lima *et al*. (2008).

A study conducted by Paull and John (2006) found that organic potatoes had higher amounts of natural biotoxins like solanine.

Maga *et al.* (1976); Schutz and Lorenz (1976); Haglund *et al*. (1999); Weibel *et al*. (2000) and Reganold *et al*. (2001) found that organic growing methods produce more flavourful fruits and vegetables. But DeEll and Prange (1992) and Caussiol and Joyce (2004) did not observe any consistent variation in the flavour and texture of organically and conventionally grown apples and bananas. Vogtmann *et al*. (1993) indicated that organic tomatoes had a better taste.

Organic products are safe, clean, more nutritious, healthy, better tasting and environmentally friendlier than conventionally grown foods (FAO, 2000; Saba and Messina, 2003). Rembialkowska (2003) concluded that organic crops have better taste, smell and shelf life with positive impact on animal and human health. Zhao *et al*. (2007) also observed better taste for organic produce when compared to conventional foods.

Emsley and John (2001) found that organic apples are sweeter and firm than those grown conventionally. But Barrett (2007) did not observe any significant difference in colour, texture, flavour or overall quality, diced tomato texture or tomato peelability and product yield in organically grown and conventionally grown tomatoes.

Organic fertilisation of swiss chard showed positive effects on sensory characteristics such as colour and brightness of the leaves after storage (Moreira *et al*., 2003).

McMohan and Wilson (2001); Sago *et al*. (2001) and Johannessen *et al*. (2004) noticed low occurrence of pathogenic bacteria in organically grown lettuce. Bourn and Prescott (2002) and Rembialkowska (2007) found that organic farming increases the shelf life of leafy vegetables. Boonyakiat *et al.* (2007) suggested that cabbage and spinach grown under conventional system had a longer shelf life than organic vegetables.

Olson *et al*. (2006) studied the antiproliferative activity of organically and conventionally cultivated strawberries and reported that extracts from organic strawberries had higher antiproliferate activity against colon cancer and breast cancer cells than from conventional strawberries.

Materials and Methods

3. MATERIALS AND METHODS

The materials and methods used for the study entitled "Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)" are given under the following headings.

3.1. Collection of amaranthus

3.2. Quality evaluation of amaranthus

    3.2.1. Physical characters

    3.2.2. Biochemical and nutritional constituents

    3.2.3. Antinutritional factors

    3.2.4. Organoleptic evaluation

3.3. Statistical analysis

3.1. Collection of amaranthus

The leaves of amaranthus (cv. Arun) cultivated using recommended NPK and organic manures as part of the All India Co-ordinated Research Project (Vegetable Crops) were collected at their edible stage during the summer season (Feb - April) of 2010. The details of the treatments are given in Table 1. The quantity of organic manures used in each treatment was equivalent to 100 per cent recommended nitrogen.

Table 1. Quantity of organic manures and recommended NPK used in different treatments

Treatments		Quantity (per ha)
T_0	Recommended NPK (control)	50 : 50 : 50 kg
T_1	Vermicompost	5 t
T_2	Farm yard manure	20 t
T_3	Neem cake	2 t
T_4	Poultry manure	5 t

3.2. Quality evaluation of amaranthus

Amaranth leaves collected from the five treatments with a plot size of 3m x 3m for each replication were evaluated for various physical characters, biochemical and nutritional constituents, antinutritional factors and organoleptic qualities at their edible stage. The evaluation of all the quality attributes were carried out in four replicate samples.

3.2.1. Physical characters

The physical characters like plant height, yield, days to flowering, appearance and colour were evaluated.

3.2.1.1. Plant height

The plant height was recorded from the base of plant to the top most fully opened leaf at ten days after first cutting of leaves, and was recorded in centimetre.

3.2.1.2. Yield

Amaranthus was harvested at 10 – 12 days interval from each plot and yield was recorded. The total yield per hectare was worked out.

3.2.1.3. Days to flowering

Days to flowering was recorded from the date of transplanting.

3.2.1.4. Appearance

The appearance of leaves of amaranthus was assessed by visual observation.

3.2.1.5. Colour

Colour of the leaves of amaranthus was recorded at their edible stage.

3.2.2. Biochemical and nutritional constituents

Amaranth leaves were analysed for the following constituents using standard procedures.

3.2.2.1. Moisture

Moisture content of amaranthus was estimated using the procedure given by A.O.A.C (1980). To determine the moisture content five grams of amaranth was taken in a petridish and dried in hot air oven at 60-70°C, cooled in a desiccator and weighed. The process of heating and cooling was repeated until a constant weight was achieved. The moisture content was calculated from the loss in weight during drying and expressed in percentage.

3.2.2.2. Protein

The protein content was estimated by the method of A.O.A.C (1980). Samples (0.2g) were digested with 10 ml Con. H_2SO_4 after adding 0.4g of $CuSO_4$ and 3.5g K_2SO_4 in a digestion flask until the colour of the sample was converted to green. After digestion, it was diluted with water and 25 ml of 40 per cent NaOH was pumped. The distillate was collected in two per cent boric acid containing mixed indicators and then titrated with 0.2 N HCl. The nitrogen content obtained was multiplied with a factor of 6.25 to get the protein content and expressed in percentage of fresh sample.

3.2.2.3. Crude fibre

The fibre content was estimated by acid alkali method as suggested by Chopra and Kanwar (1978). Two grams of dried and powdered sample was boiled with 200 ml of 1.25 per cent sulphuric acid for thirty minutes. It was filtered through a muslin cloth and washed with boiling water. The residue was again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. Repeated the filtration and the residue was washed with 1.25 per cent sulphuric acid, water and alcohol. The residue was transferred to a preweighed ashing dish, dried, cooled and weighed and ignited in a muffle furnace at 600°C for 30 minutes, cooled in a desiccator and weighed. The crude fibre content of the sample was calculated from the loss in weight on ignition and expressed in percentage on fresh weight basis.

3.2.2.4. Starch

The starch content was estimated colorimetrically using anthrone reagent (Sadasivam and Manickam, 1992). The sample (0.5g) was extracted repeatedly with 80 per cent ethanol to remove sugars completely. The residue was dried over a water bath and 5 ml of water and 6.5 ml of 52 per cent perchloric acid were added and extracted in the cold for 20 minutes. The supernatant was pooled and made up to 100 ml. Pipetted out 0.2 ml of the supernatant and made up to one ml with water, and added four ml of anthrone reagent, heated for 8 minutes, cooled and read the OD at 630 nm.

A standard graph was prepared using serial dilution of standard glucose solution. From the graph, glucose content of the sample was computed and multiplied by a factor of 0.9 to arrive at the starch content and expressed in percentage on fresh weight basis.

3.2.2.5. Vitamin C

The vitamin C content of the sample was estimated by the method of A.O.A.C (1955) using 2, 6 dichlorophenol indophenol dye. Five grams of the sample was extracted in four per cent oxalic acid using a mortar and pestle and made up to 100 ml. Five ml of the extract was pipetted and 10 ml of four per cent oxalic acid was added and titrated against the dye until the appearance of a pink colour which persisted for a few seconds. Ascorbic acid content of the sample was calculated from the titre value and expressed in mg per 100 g of the sample.

3.2.2.6. β carotene

β carotene was estimated by the method of A.O.A.C (1980) using saturated n-butanol. To five grams of the sample, 50 ml saturated n-butanol was added, shook well for a minute and kept overnight. The supernatant was decanted and the colour intensity was noted at 435.8nm in a spectrophotometer. The β carotene was expressed in μg per 100 g of the sample and converted to fresh weight basis.

3.2.2.7. Calcium

The calcium content was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982). One gram of dried and powdered sample was predigested with 10 ml of 9:4 mixture of nitric acid and perchloric acid and was made up to 100 ml. Ten ml of the made up solution was again diluted to 100 ml. This solution was read directly in atomic absorption spectrophotometer and calcium content was expressed in mg per 100 g of fresh sample.

3.2.2.8. Phosphorus

The phosphorus content was analysed colorimetrically as suggested by Jackson (1973), which gives yellow colour with nitric acid vandate molybdate reagent. To five ml of pre-digested aliquot, five ml of nitric acid vandate molybdate reagent was added and made up to 50 ml with distilled water. After 10 minutes, the OD was read at 420 nm.

A standard graph was prepared using the serial dilution of standard phosphorus solution. The phosphorus content of the sample was estimated from the standard graph and expressed in mg per 100 g of fresh sample.

3.2.2.9. Sodium

The sodium content was estimated using flame photometer as suggested by Jackson (1973). The diacid extract was made up to 100 ml and 10 ml of the made up solution was again diluted to 100 ml. This solution was directly fed in the flame photometer and sodium content was expressed in mg per 100 g on fresh weight basis.

3.2.2.10. Potassium

The method suggested by Jackson (1973) was followed for the estimation of potassium using flame photometer. The diacid extract was made up to 100 ml and10 ml of the made up solution was diluted to 100 ml and 1 ml of the made up solution was again diluted to 100 ml. This solution was read directly in flame photometer and potassium content was expressed in mg per 100 g on fresh weight basis.

3.2.2.11. Magnesium

The magnesium content was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982). The diacid extract was made up to 100 ml. This solution was read directly in atomic absorption spectrophotometer and magnesium content was expressed in mg per 100 g of fresh sample.

3.2.2.12. Iron

Iron content was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982). The diacid extract was made up to 100 ml and 10 ml of the made up solution was again diluted to 100 ml. This solution was read directly in atomic absorption spectrophotometer and iron content was expressed in mg per 100 g of fresh sample.

3.2.2.13. Zinc

The zinc content was estimated using atomic absorption spectrophotometric method as suggested by Perkin-Elmer (1982). The diacid extract was made up to 100 ml and was read directly in atomic absorption spectrophotometer and zinc content was expressed in mg per 100 g of fresh weight basis.

3.2.2.14. Total carotenoid

Total carotenoid was estimated using 80 per cent acetone as suggested by Ranganna (1977). One gram of the sample was ground with 80 per cent acetone, centrifuged, and made up to 100 ml using 80 per cent acetone. The absorbance was read at 480 and 510nm and expressed in mg per 100 g on fresh weight basis.

3.2.2.15. Total chlorophyll

Total chlorophyll was estimated using 80 per cent acetone as suggested by Ranganna (1977). One gram of the sample was ground with 80 per cent acetone and centrifuged. This solution was made up to 100 ml using 80 per cent acetone. The absorbance was read at 645 and 663nm and expressed in mg per 100 g of fresh weight basis.

3.2.2.16. Total phenols

The phenol content was estimated colorimetrically using the method suggested by Sadasivam and Manickam (1992). One gram of fresh sample was extracted with 80 per cent ethanol twice and the supernatant was pooled. Evaporated the supernatant to dryness. The residue was dissolved in a known volume of distilled water from which one ml was pipetted and made up the volume to three ml with distilled water to which 0.5 ml of Folin- Ciocalteau reagent was added. After three minutes, two ml of 20 per cent sodium carbonate was added and mixed thoroughly and heated for exactly one minute, cooled and measured the absorbance in spectrophotometer at 650nm against a reagent blank. A standard graph was prepared using serial dilutions of standard catechol solution. From the standard graph, the phenol content of the sample was estimated.

3.2.2.17. Anthocyanin

Ten grams of sample was blended with 10 ml of ethanolic HCl and transferred to a 100 ml volumetric flask and made up to volume. The sample was stored overnight at 4^0C, filtered and recorded the optical density of the filtrate at 535nm in a spectrophotometer. The anthocyanin content was expressed in mg per 100 g of fresh sample.

3.2.3. Antinutritional factors

3.2.3.1. Oxalate

Oxalate content in the sample was analysed colorimetrically as suggested by Marderosian *et al*. (1979). To 0.5 g of dried and powdered sample, 10 ml of distilled water and 10 ml of citric acid reagent were added. The sample was extracted by shaking for 10 minutes at room temperature and filtered. The precipitate was dissolved in 50 ml of 0.4 N HCl by shaking for 10 minutes and was filtered again. Two ml of filtrate was taken and two ml of diluted iron ferron reagent was added and the absorbance was read at 540nm in a spectrophotometer. The oxalate content of the sample was calculated from the standard graph and converted to fresh weight basis and expressed in gram per 100g.

3.2.3.2. Nitrate

Nitrate content was estimated by the method suggested by Marderosian *et al.* (1979). One gram of the dried and powdered sample was extracted in 100 ml of distilled water for 30 minutes by shaking and then filtered. To five ml of the filtrate, 0.1 g of 3,4 dimethylphenol was added, followed by 10 ml of Con. sulphuric acid and allowed to stand for 10 minutes. To this, 30 ml of distilled water was added and kept the flask under running water for 30 minutes. Later, the contents were steam distilled and 25 ml of distillate was collected in a volumetric flask containing 3 ml of 5 per cent NaOH. The colour intensity was measured in a spectrophotometer at 430nm.

A standard graph was prepared using a serial dilution of standard sodium nitrate solution and the content of nitrate in the sample was estimated and expressed in gram per 100 g of fresh sample.

3.2.4. Organoleptic evaluation

Organoleptic evaluation of amaranth leaves was conducted after cooking at laboratory level, by a panel of selected judges using score card.

3.2.4.1. Selection of judges

A series of organoleptic trials were carried out using simple triangle test at laboratory level to select a panel of ten judges between the age group of 18 to 35 years as suggested by Jellinek (1985).

3.2.4.2. Preparation of score card

The sensory evaluation of the products was carried out using score card method (Swaminathan, 1974). Score card containing six quality attributes such as appearance, colour, flavour, texture, taste and overall acceptability was prepared for the evaluation of the cooked amaranth. Each of the above mentioned qualities were assessed by a nine point hedonic scale. The score card used for the evaluation of amaranthus is given in Appendix 1.

3.2.4.3. Preparation of the samples for acceptability studies

The fresh leaves (100 g) were washed in water and cut into small pieces using a stainless steel knife. Heated 10 ml coconut oil and spluttered mustard. Then, amaranth leaves were added and cooked under low flame by sprinkling water and adding salt to taste.

3.3. Statistical analysis

The data on plant height, yield and days to flowering were analysed in Randomized Block Design (RBD). The biochemical constituents were analysed in Completely Randomized Design (CRD) and the treatments were grouped by Duncan's Multiple Range Test (DMRT). For organoleptic studies Kendall's Coefficient of Concordance was used to assess the degree of agreement among the judges.

Result

4. RESULT

The results pertaining to the study entitled "Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)" is presented under the following headings.

4.1. Physical characters
4.2. Biochemical and nutritional constituents
4.3. Antinutritional factors
4.4. Organoleptic qualities
4.5. Selection of the most desirable treatment

4.1. Physical characters

The physical characters such as plant height, yield, days to flowering, appearance and colour of amaranthus grown using different treatments viz. recommended NPK (T_0), vermicompost (T_1), farm yard manure (T_2), neem cake (T_3) and poultry manure (T_4) were recorded and the results are furnished in Table 2.

4.1.1. Plant height

The height of plants varied from 61.97 cm to 130.30 cm with the maximum and minimum height in amaranthus grown with poultry manure and recommended NPK respectively. The plant height of amaranthus cultivated using vermicompost, farm yard manure and neem cake were found to be 71.37 cm, 102.12 cm and 66.85 cm respectively (Fig.1).

It was found that the plant height of amaranthus grown in different treatments varied significantly from each other except in the case of T_3 in which neem cake was applied. The variation noticed in the plant height of T_0 (recommended NPK) and T_3 (neem cake) as well as T_1 (vermicompost) and T_3 (neem cake) was statistically nonsignificant. However, the plant height of amaranthus grown in neem cake varied significantly from the plant height noticed in T_2 (farm yard manure) and T_4 (poultry manure). When compared to recommended NPK, the plant height of amaranthus grown

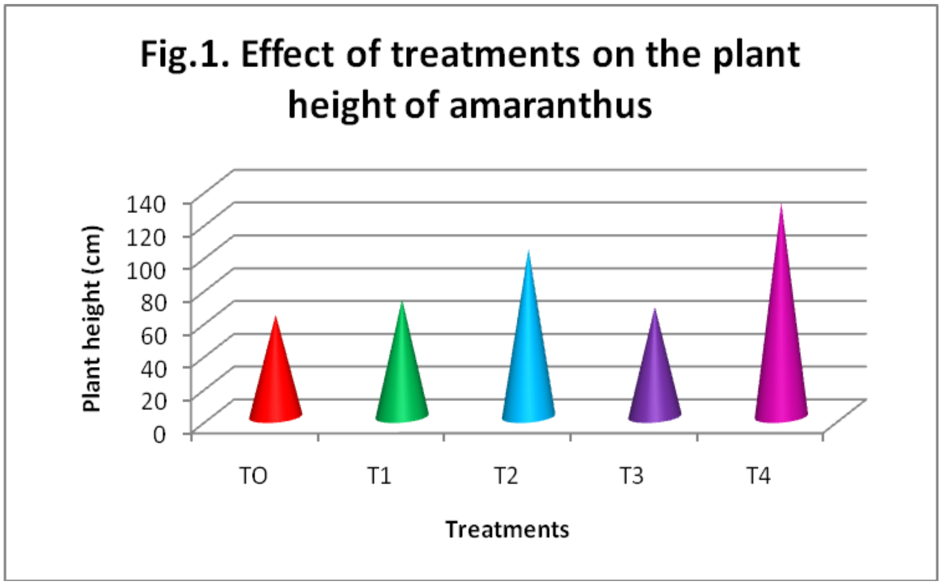


Fig.1. Effect of treatments on the plant height of amaranthus

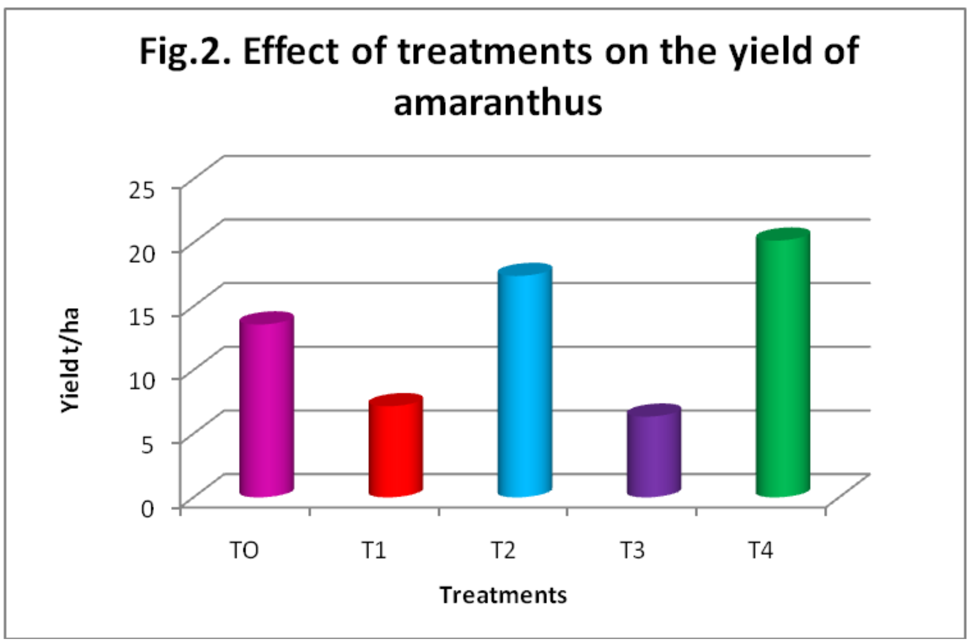


Fig.2. Effect of treatments on the yield of amaranthus

T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

Table. 2 Effect of treatments on the physical characters of amaranthus

Treatments		Mean			Appearance	Colour
		Plant height (cm)	Yield (t ha^{-1})	Days to flowering		
T_0	Recommended NPK(control)	61.97^{d}	13.58^{b}	102.25^{c}	Good	Maroon red
T_1	Vermicompost	71.37^{c}	7.16^{c}	93.50^{d}	Poor	Maroon red
T_2	Farm yard manure	102.12^{b}	17.39^{a}	111.50^{b}	Good	Maroon red
T_3	Neem cake	66.85^{cd}	6.34^{c}	108.75^{bc}	Poor	Maroon red
T_4	Poultry manure	130.30^{a}	20.17^{a}	125.75^{a}	Good	Maroon red

Values having different superscripts differ significantly

in farm yard manure, vermicompost and poultry manure was found to be significantly high.

4.1.2. Yield

The mean yield of amaranthus varied from 6.34 to 20.17 t ha^{-1}. The maximum yield was noticed in amaranthus cultivated using poultry manure and minimum in neem cake. The mean yield of amaranthus in T_0 (recommended NPK) was 13.58 t ha^{-1} and was significantly higher than the yield in T_1 (vermicompost) and T_3 (neem cake). The yield of amaranthus grown using poultry manure and farm yard manure was found to be significantly higher than the yield obtained in T_0 (recommended NPK). The variation noticed in the yield of amaranthus grown with vermicompost and neem cake as well as farm yard manure and poultry manure was also found to be statistically nonsignificant. The effect of treatments on the yield of amaranthus is depicted in Fig.2.

4.1.3. Days to flowering

Days to flowering (Mean) of amaranthus grown using different manures varied from 93.50 days for vermicompost to 125.75 days for poultry manure. The amaranthus grown as per recommended NPK flowered in 102.25 days (Fig.3).

The days to flowering of amaranthus was found to be significantly high in the treatment grown using poultry manure and farm yard manure when compared to recommended NPK. The days to flowering of amaranthus grown with vermicompost was found to be significantly lower when compared to recommended NPK. The variation noticed in the days to flowering of amaranthus grown using neem cake and farm yard manure as well as neem cake and recommended NPK was statistically nonsignificant.

4.1.4. Appearance

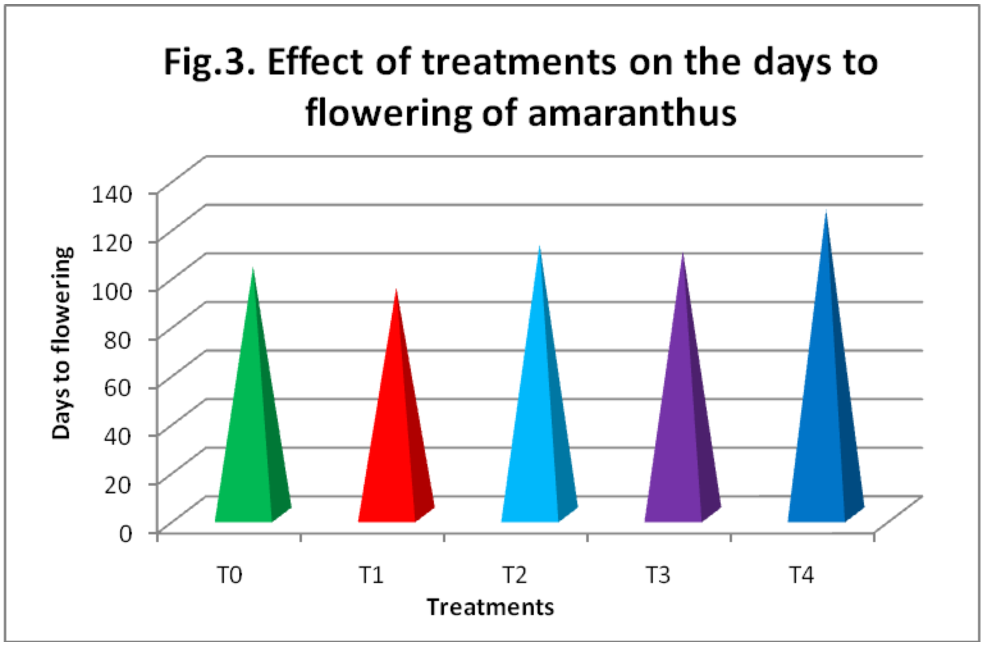
The appearance of amaranthus cultivated using recommended NPK, farm yard manure and poultry manure was found to be good at the time of harvest, while in the other two treatments in which vermicompost and neem cake were used, the appearance of the leaves was found to be poor (Plate 1).

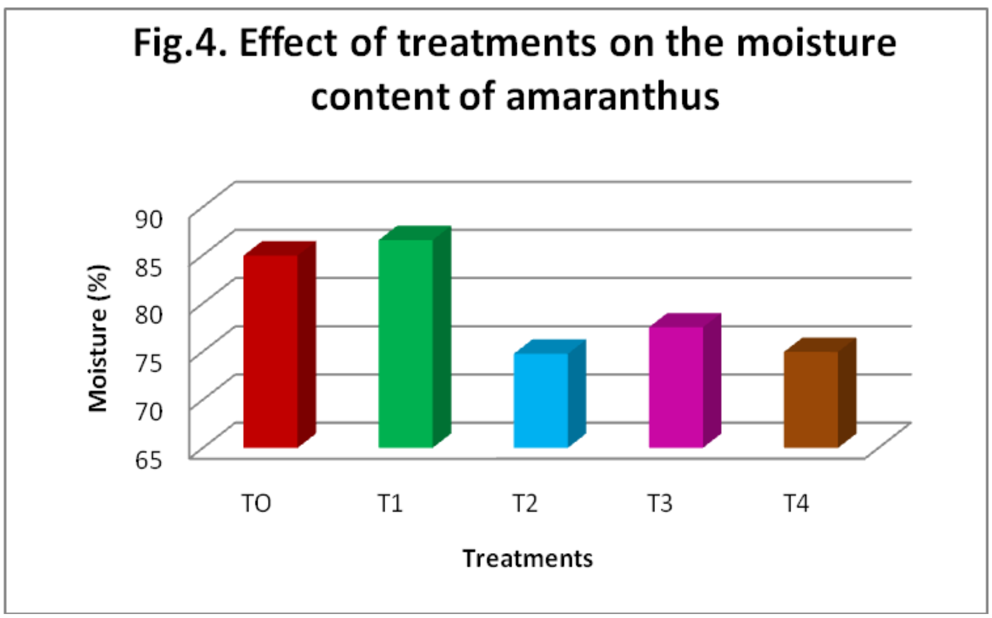
4.1.5. Colour

The colour of amaranthus cultivated using different organic manures as well as recommended NPK was found to be maroon red.

4.2. Biochemical and nutritional constituents

Organically and inorganically cultivated amaranthus were analysed for 17 constituents like moisture, protein, crude fibre, starch, vitamin C, beta carotene, calcium, phosphorus, sodium, potassium, magnesium, iron, zinc, carotenoids, chlorophyll, total phenols and anthocyanins. The constituents present in amaranthus grown using four different organic manures were compared with the constituents present in amaranthus grown inorganically and are presented from 4.2.1 to 4.2.17.





T_0-Recommended NPK T_1- Vermicompost
T_2- Farm yard manure T_3- Neem cake
T_4- Poultry manure

Recommended NPK

Farm yard manure

Poultry manure

Neem cake

Vermicompost

Plate 1. Appearance of amaranthus cultivated using various treatment

4.2.1. Moisture

The moisture content of amaranthus grown using different treatments are given in Table.3 and Fig.4. The mean moisture content varied from 74.75 per cent in amaranthus grown with farm yard manure to 86.55 per cent in those grown using vermicompost. The moisture content of amaranthus grown with recommended NPK was found to be 84.95 per cent and was found to be higher than the content observed when farm yard manure (74.75%), neem cake (77.50%) and poultry manure (74.95%) were used as manures. The mean moisture content of amaranthus grown using vermicompost (86.55%) was found to be higher than those grown as per recommended NPK. However, the variation was found to be statistically nonsignificant.

The variation noticed in the moisture content of amaranthus grown as per recommended NPK and those grown using other four organic manures were found to be statistically nonsignificant. However, the highest moisture content observed in amaranthus grown in vermicompost varied significantly from the moisture content of amaranthus grown in farm yard manure as well as poultry manure.

4.2.2. Protein

The mean protein content of amaranthus varied from 2.03 per cent to 3.63 per cent (Table 3) with the highest content in amaranthus cultivated using poultry manure and the lowest in amaranthus grown as per recommended NPK. The protein content of amaranthus which was cultivated using organic manures such as vermicompost, farm yard manure, neem cake and poultry manure were found to be significantly higher than the protein content of amaranthus grown as per recommended NPK. The effect of treatments on the protein content of amaranthus is illustrated in Fig.5.

Among the four different organic manures also significantly high protein content was observed in amaranthus grown using poultry manure when compared to vermicompost, farm yard manure and neem cake. The variation noticed in the protein

Fig.5. Effect of treatments on the protein content of amaranthus

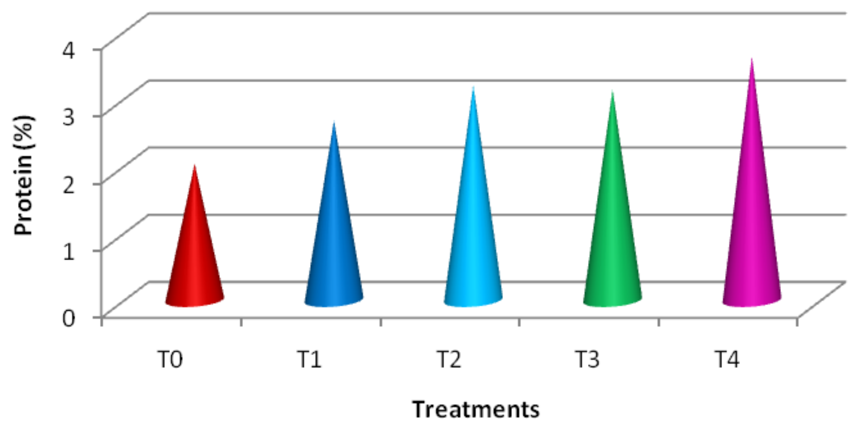
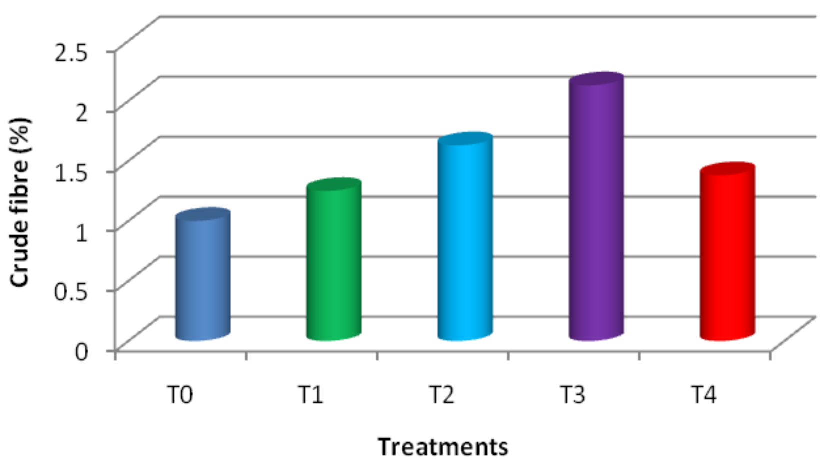


Fig.6. Effect of treatments on the crude fibre content of amaranthus



T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

Table. 3 Effect of treatments on the moisture, protein, crude fibre and starch content of amaranthus (per 100g)

Treatments		Mean ± SE			
		Moisture (%)	Protein (%)	Crude fibre (%)	Starch (%)
T_0	Recommended NPK(control)	84.95^{ab} ± 1.15	2.03^{d} ± 0.02	1.00^{b} ± 0.35	0.45^{a} ±0.03
T_1	Vermicompost	86.55^{a} ± 1.35	2.67^{c} ± 0.02	1.25^{b} ± 0.25	0.23^{b} ±0.03
T_2	Farm yard manure	74.75^{b} ± 2.31	3.20^{b} ± 0.07	1.63^{ab} ± 0.13	0.44^{a} ± 0.07
T_3	Neem cake	77.50^{ab} ±3.87	3.14^{b} ± 0.04	2.13^{a} ± 0.24	0.39^{a} ± 0.07
T_4	Poultry manure	74.95^{b} ±6.06	3.63^{a} ± 0.03	1.38^{ab}± 0.31	0.55^{a} ± 0.01

Values having different superscripts differ significantly

content of amaranthus grown in farm yard manure and neem cake was found to be statistically nonsignificant.

4.2.3. Crude fibre

The crude fibre content of amaranthus grown using different treatments are furnished in Table 3. and Fig.6. The mean crude fibre content varied from 1.00 per cent to 2.13 per cent with the highest content in amaranthus grown in neem cake and lowest in amaranthus grown as per recommended NPK. The mean crude fibre content of amaranthus grown using vermicompost, farm yard manure and poultry manure were found to be 1.25, 1.63 and 1.38 per cent respectively. The crude fibre content of amaranthus grown with organic manures was found to be higher than those grown as per recommended NPK.

On the basis of statistical analysis, the highest crude fibre content which was noticed in amaranthus grown in T_3 (neem cake) varied significantly with the content observed in T_0 (recommended NPK) and T_1 (vermicompost). However, the variation observed in the crude fibre content of amaranthus grown using farm yard manure, neem cake and poultry manure was found to be statistically nonsignificant.

4.2.4. Starch

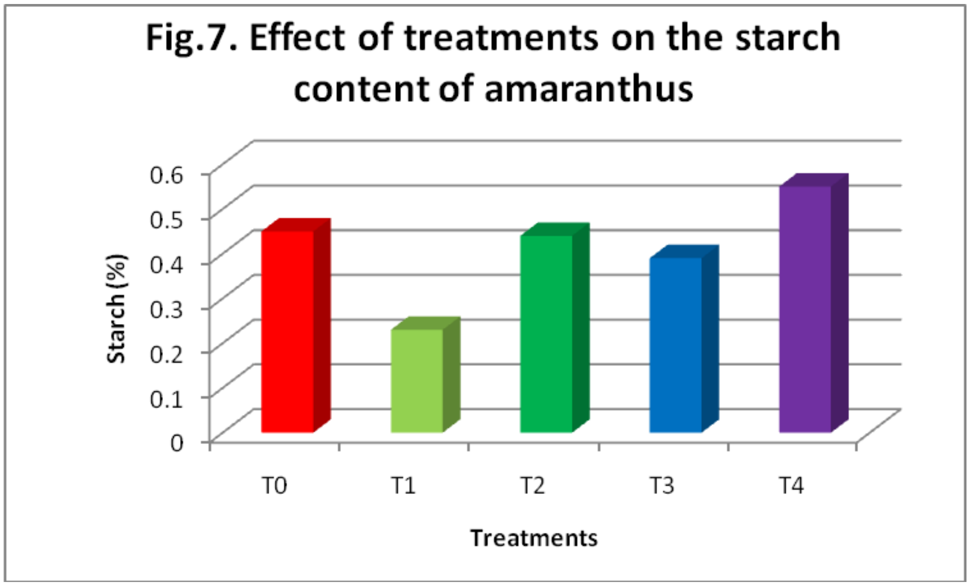
Starch content of amaranthus grown with five different treatments is furnished in Table 3. and Fig.7. The mean starch content ranged from 0.23 per cent in amaranthus grown using vemicompost to 0.55 per cent in amaranthus grown using poultry manure. The starch content of amaranthus cultivated with recommended NPK was found to be higher than the content of amaranthus grown with all organic manures except the one which was grown using poultry manure.

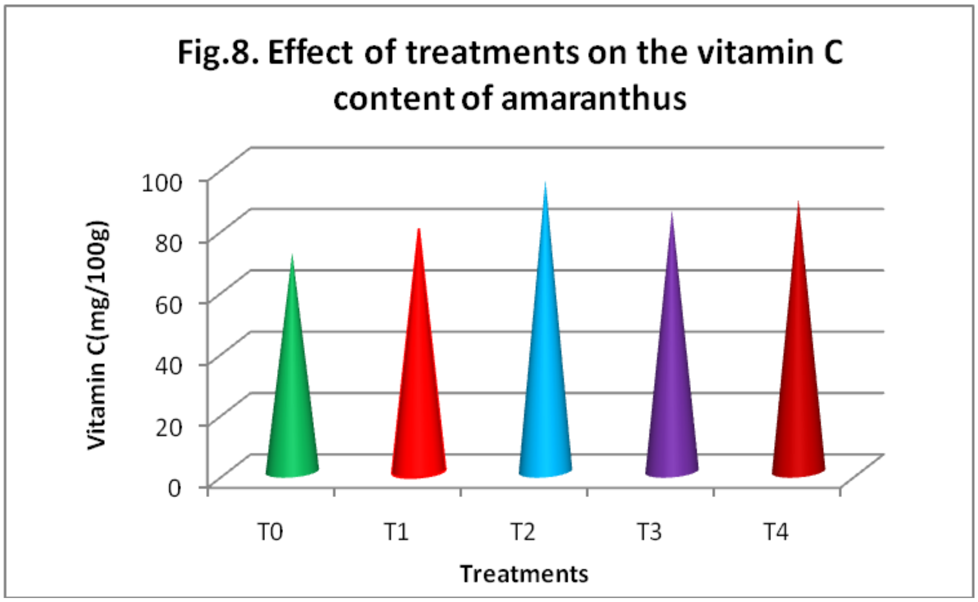
The lowest starch content observed in T_1 which was grown using vermicompost varied significantly from that of all other treatments. However, the variation observed in the starch content of amaranthus grown using NPK, farm yard manure, neem cake and poultry manure was statistically nonsignificant.

4.2.5. Vitamin C

Vitamin C content of amaranthus varied from 71.25 mg to 95 mg $100g^{-1}$ (Table 4). The amaranthus cultivated as per recommended NPK had the lowest vitamin C content and the one which was grown using farm yard manure had the highest content. The vitamin C content of amaranthus grown using vermicompost, neem cake and poultry manure was found to be 78.75 mg, 85 mg and 88.75 mg $100g^{-1}$ respectively. The vitamin C content of amaranthus cultivated in different treatment is furnished in Fig.8.

The variation observed in the vitamin C content of amaranthus cultivated using four different organic manures was found to be statistically nonsignificant. However, the lowest vitamin C content noticed in amaranthus grown as per recommended NPK varied significantly from the content observed in T_2 in which farm yard manure was used.





T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

Table. 4 Effect of treatments on the vitamin C and beta carotene content of amaranthus (per 100g)

Treatments		Mean ± SE	
		Vitamin C (mg)	Beta carotene (µg)
T_0	Recommended NPK(control)	$71.25^{b} \pm 3.75$	$2282.50^{b} \pm 46.24$
T_1	Vermicompost	$78.75^{ab} \pm 7.18$	$3055.75^{a} \pm 40.64$
T_2	Farm yard manure	$95.00^{a} \pm 2.89$	$3009.75^{a} \pm 17.25$
T_3	Neem cake	$85.00^{ab} \pm 6.12$	$3043.0^{a} \pm 22.61$
T_4	Poultry manure	$88.75^{ab} \pm 6.57$	$2122.0^{c} \pm 19.85$

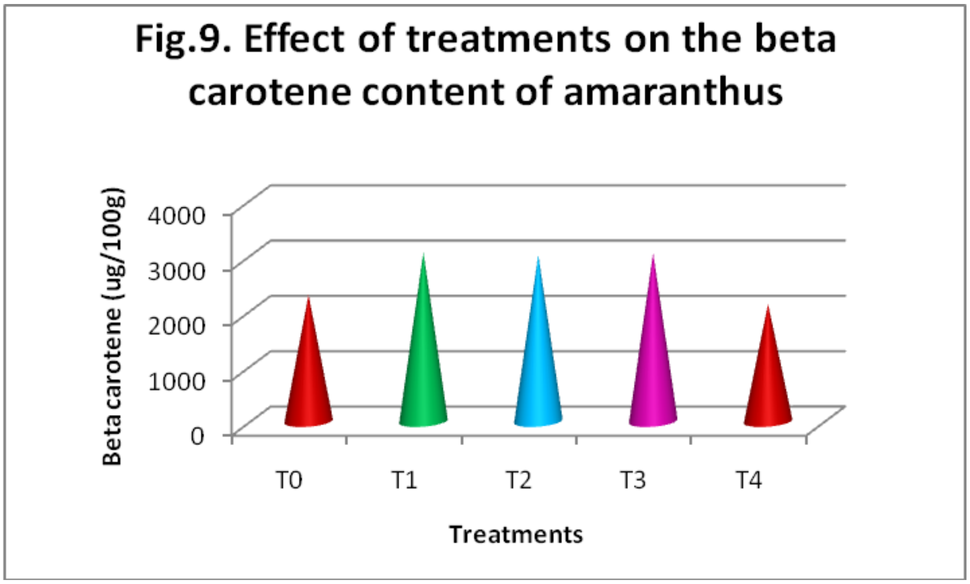
Values having different superscripts differ significantly

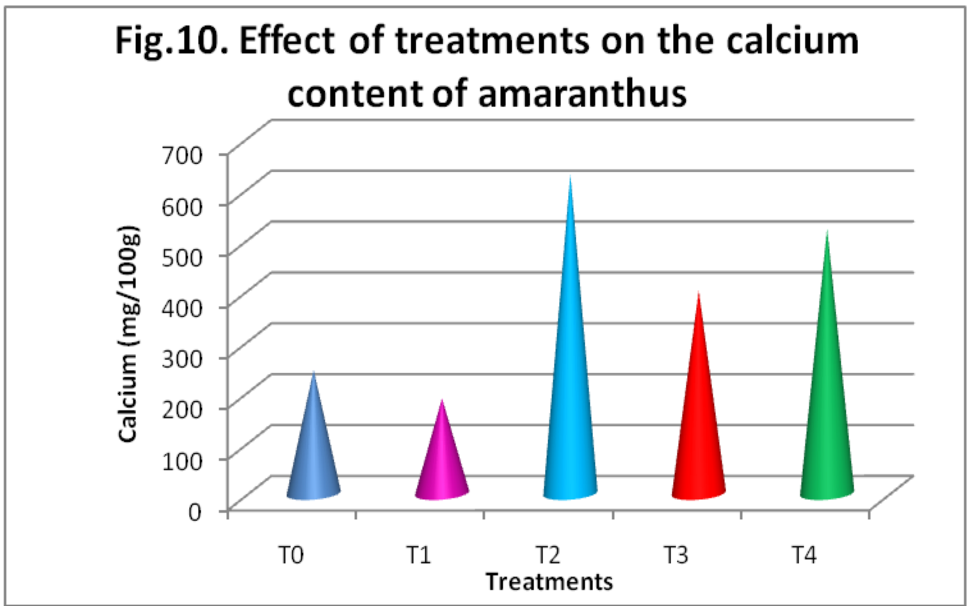
4.2.6. Beta carotene

The highest beta carotene content was noticed in amaranthus grown in vermicompost followed by T_3 in which neem cake was applied (Table 4 and Fig.9). The lowest beta carotene content was observed in amaranthus in which poultry manure was applied. The beta carotene content of amaranthus grown using vermicompost, farm yard manure and neem cake did not vary significantly between each other. However, the beta carotene content of amaranthus observed in T_0 (recommended NPK) varied significantly from the content of amaranthus grown using organic manures.

4.2.7. Calcium

The mean calcium content of amaranthus grown under different treatments is furnished in Table 5 and Fig.10. The content varied from 186.58 mg to 627.66 mg $100g^{-1}$ with the highest and lowest calcium contents in amaranthus cultivated using farm yard





T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

manure and vermicompost respectively. The mean calcium content of amaranthus grown as per recommended NPK (242.63 mg $100g^{-1}$) was found to be significantly higher than the calcium content of amaranthus in which vermicompost (186.58 mg $100g^{-1}$) was applied. However, the calcium content of amaranthus grown under T_0 was found to be significantly lower than that of the amaranthus cultivated in T_2, T_3 and T_4.

The variation observed in the calcium content of amaranthus cultivated using different treatments was found to be statistically significant.

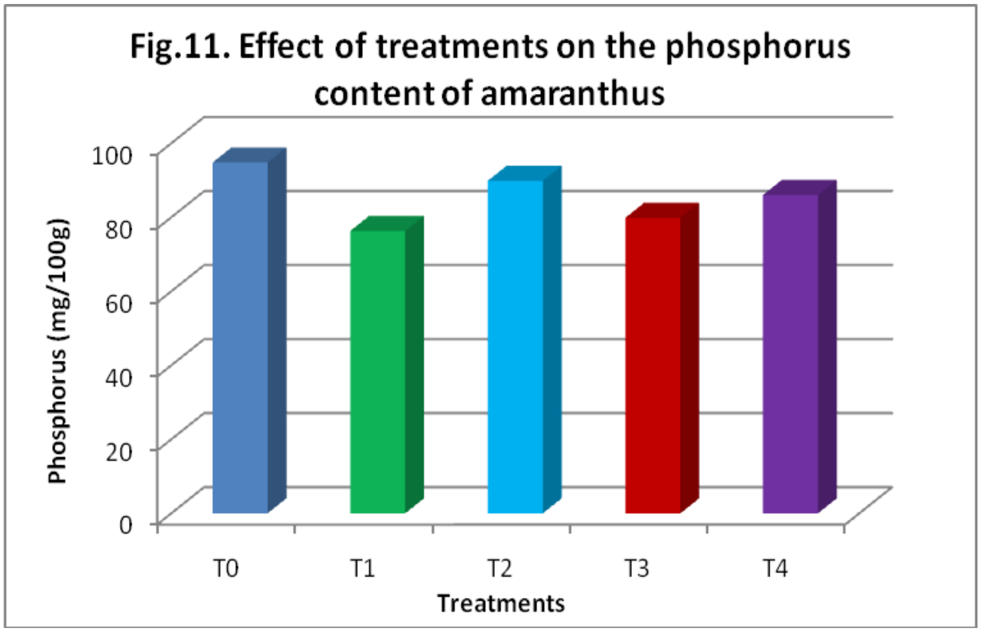
4.2.8. Phosphorus

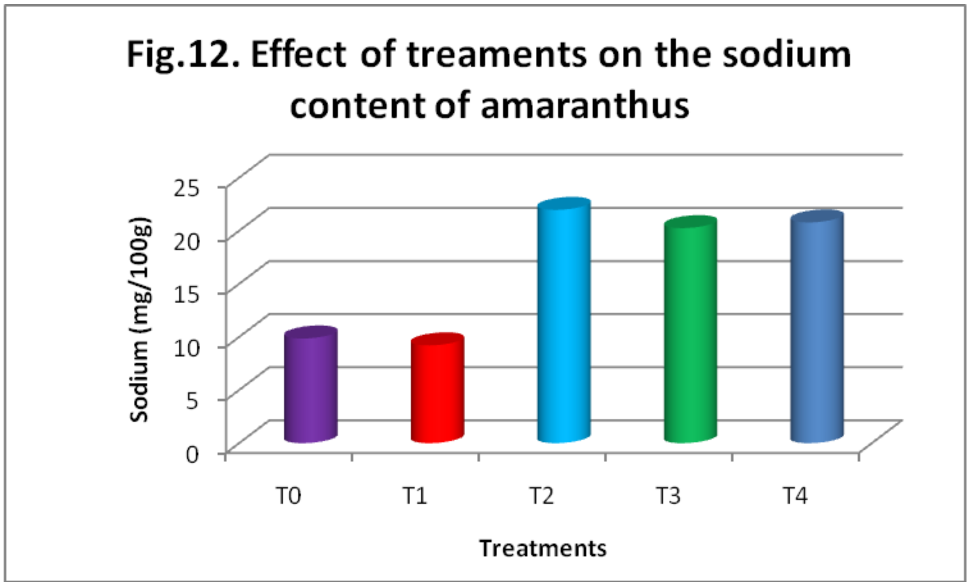
The phosphorus content of amaranthus varied from 76.29 mg to 94.80 mg $100g^{-1}$ with the highest content in amaranthus grown as per recommended NPK and lowest in amaranthus cultivated with vermicompost (Table 5). Among the organic manures applied, the amaranthus grown in farm yard manure had the highest phosphorus content of 89.85 mg $100g^{-1}$ compared to amaranthus grown in vermicompost, neem cake and poultry manure. The phosphorus content of amaranthus grown in different treatments are furnished in Fig.11.

The phosphorus content of amaranthus cultivated organically was found to be significantly lower than the phosphorus content of amaranthus grown as per recommended NPK except the one which was cultivated in farm yard manure. The variation observed in T_0 and T_2, T_1 and T_3 as well as T_2 and T_4 was found to be statically nonsignificant. The variation observed in the phosphorus content of amaranthus grown in vermicompost and farm yard manure, farm yard manure and neem cake as well as vermicompost and poultry manure was found to be statistically significant.

4.2.9. Sodium

The sodium content of amaranthus is furnished in Table 5 and Fig 12. The sodium content of amaranthus cultivated using different treatments varied from 9.21 mg to 21.97 mg $100g^{-1}$ with the highest and lowest contents in amaranthus grown with farm yard manure and vermicompost respectively. Sodium content of amaranthus grown as per





T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

Table. 5. Effect of treatments on the calcium, phosphorus, sodium, potassium, and magnesium content of amaranthus (per 100g)

Treatments		Mean ± SE				
		Calcium (mg)	Phosphorus (mg)	Sodium (mg)	Potassium (mg)	Magnesium (mg)
T_0	Recommended NPK(control)	242.63^{d} ±2.25	94.80^{a} ±2.52	9.86^{c} ±0.07	978.05^{a}±110.15	199.03^{ab}±33.61
T_1	Vermicompost	186.58^{e} ±1.48	76.29^{d} ±1.80	9.21^{d} ±0.13	954.95^{ab} ±77.6	128.45^{b} ±2.08
T_2	Farm yard manure	627.66^{a} ±3.70	89.85^{ab} ±2.60	21.97^{a} ±0.33	984.75^{a} ±78.5	280.90^{a} ±42.77
T_3	Neem cake	397.98^{c} ±7.98	79.86^{cd} ±1.71	20.25^{b}± .26	705.50^{c} ±74.2	223.88^{ab} ±8.74
T_4	Poultry manure	520.60^{b} ±3.34	86.03^{bc} ±3.91	20.79^{b} ±0.14	726.45^{bc} ±72.3	266.78^{a} ±46.56

Values having different superscripts differ significantly

recommended NPK was found to be 9.86 mg and the content significantly varied from the content of amaranthus grown with different organic manures.

The sodium content of amaranthus grown using recommended NPK and organic manures varied significantly between each other. However, the variation noticed in the sodium content of amaranthus grown using neem cake and poultry manure was found to be statistically nonsignificant.

4.2.10. Potassium

The potassium content of amaranthus is presented in Table 5. The mean potassium content of amaranthus varied from 705.50 mg in T_3 to 984.75 mg $100g^{-1}$ in T_2. Statistically, the potassium content of amaranthus grown in neem cake and poultry manure was found to be significantly lower than the potassium content of amaranthus grown as per recommended NPK. However, the variation noticed in the potassium content of amaranthus grown in vermicompost, farm yard manure and recommended NPK was found to be statistically nonsignificant. The potassium content of amaranthus grown in different treatments are furnished in Fig.13.

Fig.13. Effect of treatments on the potassium content of amaranthus

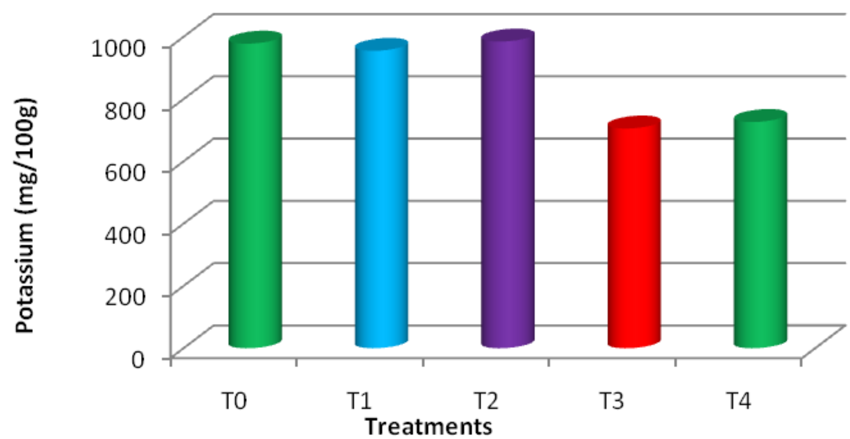
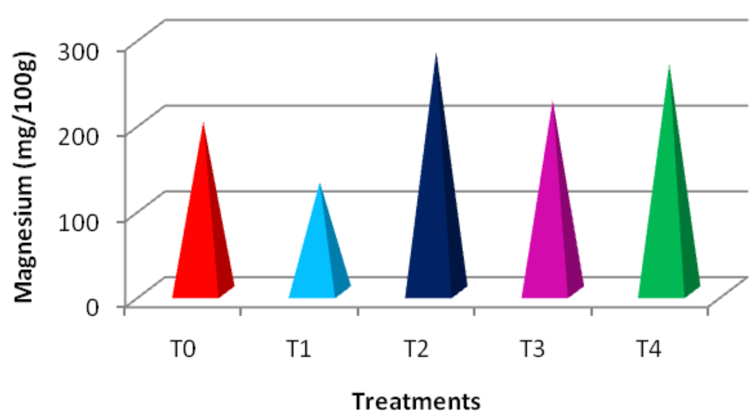


Fig.14. Effect of treatments on the magnesium content of amaranthus



T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

4.2.11. Magnesium

The mean magnesium content of amaranthus was found to be in the range of 128.45 mg and 280.90 mg $100g^{-1}$ (Table 5) and (Fig.14). The highest magnesium was found in amaranthus grown using farm yard manure and lowest in amaranthus grown using vermicompost. The control which was cultivated as per recommended NPK had a mean magnesium content of 199.03 mg $100g^{-1}$ and was found to be higher than the magnesium content of amarathus grown in vermicompost. But, the increase was statistically insignificant. The amaranthus grown in farm yard manure, neem cake and poultry manure had a magnesium content of 280.90, 223.88 and 266.78 mg $100g^{-1}$ respectively and was found to be higher than the magnesium content of T_0. However, the increase was found to be statistically nonsignificant.

The variation observed in the magnesium content of amaranthus grown under different organic treatments (T_1 - T_4) as well as those grown as per recommended NPK (To) was found to be statistically insignificant. However, the magnesium content of amaranthus grown in T_1 varied significantly from T_2 and T_4.

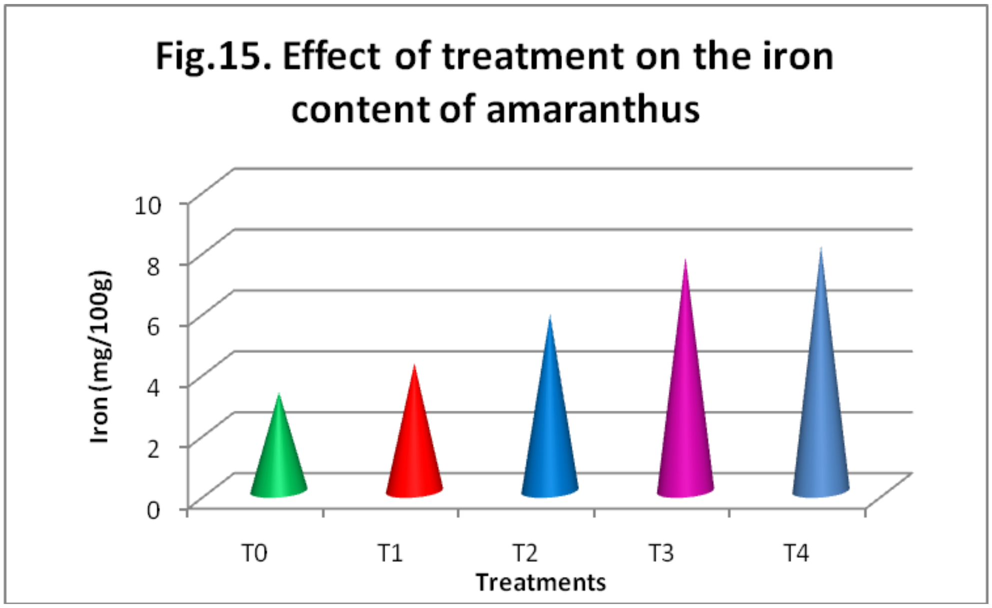
4.2.12. Iron

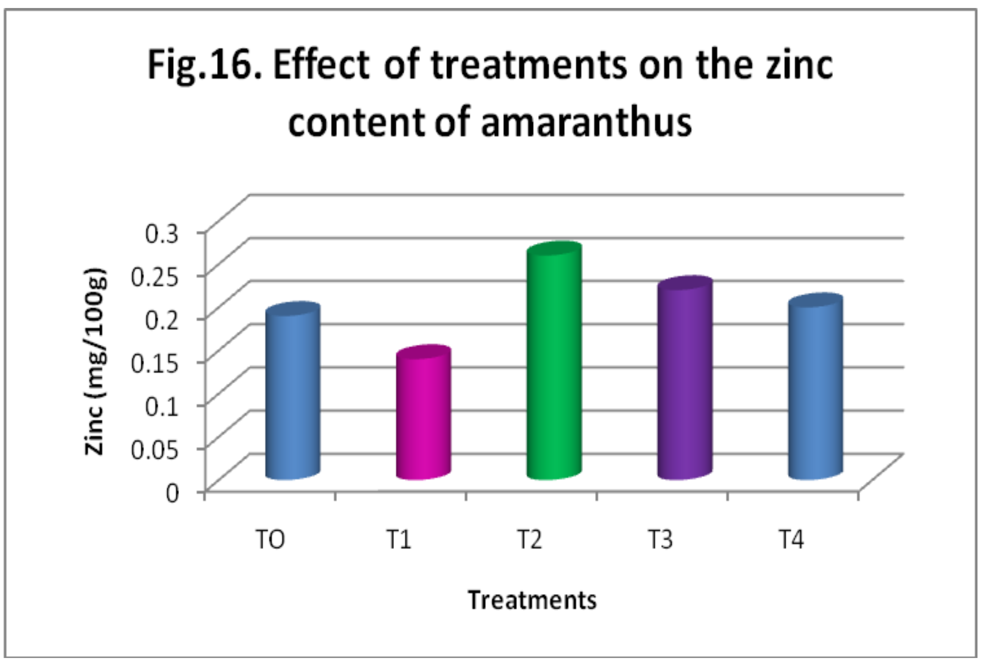
The iron content of amaranthus grown under different treatments is shown in Table 6 and Fig 15. The mean iron content ranged from 3.25 mg $100g^{-1}$ in amaranthus grown with recommended NPK to 8.06 mg $100g^{-1}$ in those grown with poultry manure. The mean iron content of amaranthus grown as per recommended NPK was found to be significantly lower than the iron content of amaranthus grown with different organic manures.

Statistically, significant variation in the iron content of amaranthus was observed between each treatment.

4.2.13. Zinc

Zinc content of amaranthus grown under different treatments is given in the Table 6. The mean zinc content varied from 0.14 mg to 0.26 mg $100g^{-1}$. The lowest content was





T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

Table. 6. Effect of treatments on the iron and zinc content of amaranthus (per 100g)

Treatments		Mean ± SE	
		Iron (mg)	**Zinc (mg)**
T_0	Recommended NPK(control)	3.25^{e} ±0.04	0.19^{bc} ±0.01
T_1	Vermicompost	4.19^{d} ±0.05	0.14^{c} ±0.01
T_2	Farm yard manure	5.80^{c} ±0.05	0.26^{a} ±0.03
T_3	Neem cake	7.68^{b} ±0.13	0.22^{ab} ±0.01
T_4	Poultry manure	8.06^{a} ±0.12	0.20^{abc} ±0.02

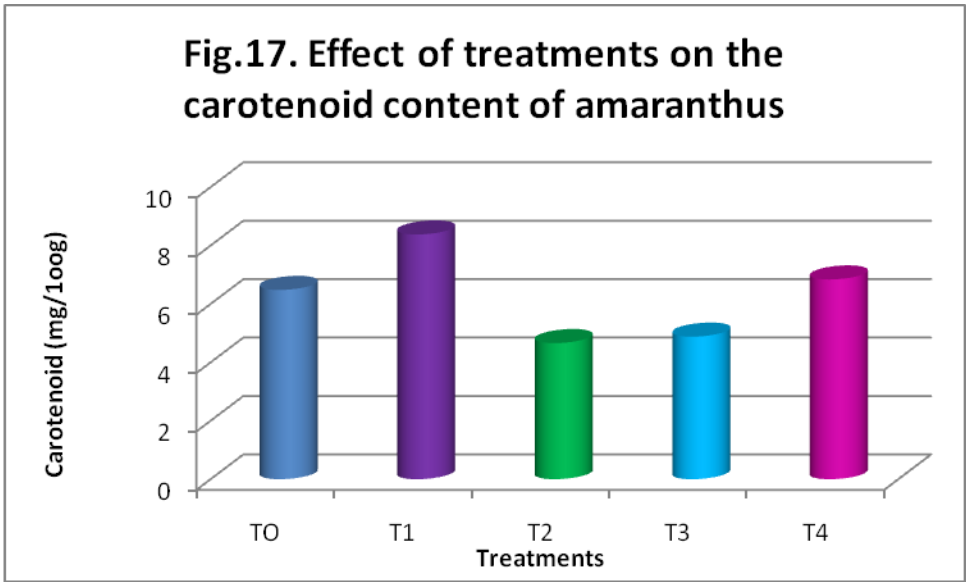
Values having different superscripts differ significantly

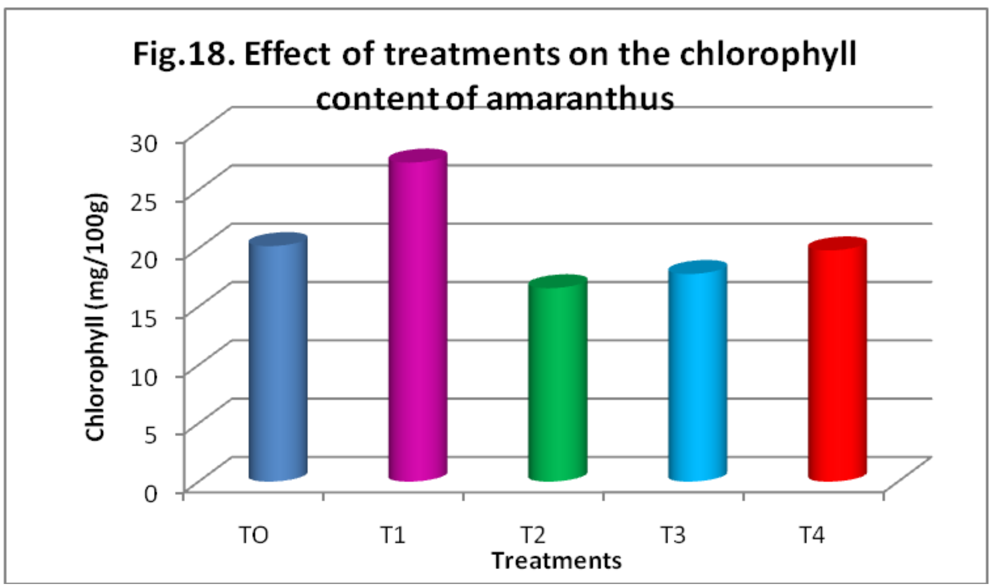
found in amaranthus grown in vermicompost and the highest in amaranthus grown in farm yard manure. The amaranthus grown in farm yard manure (0.26 mg $100g^{-1}$), neem cake (0.22 mg $100g^{-1}$) and poultry manure (0.20 mg $100g^{-1}$) had higher zinc content than those grown as per recommended NPK. However, the variation was found to be statistically significant only in the treatment in which farm yard manure was applied. The effect of treatments on the zinc content of amaranthus is illustrated in Fig.16.

The highest zinc content observed in amaranthus grown with farm yard manure varied significantly from those grown in vermicompost and as per recommended NPK. Significant variation was not observed in the zinc content of amaranthus grown in T_2, T_4 and T_3. The variation observed in the zinc content of amaranthus cultivated in neem cake, poultry manure and recommended NPK was also found to be statistically nonsignificant.

4.2.14. Carotenoid

The mean carotenoid content of amaranthus is given in the Table 7 and Fig.17. The caroteinoid content varied from 4.66 mg $100g^{-1}$ in amaranthus grown with farm yard manure to 8.38 mg $100g^{-1}$ in the amaranthus in which vermicompost was used. The amaranthus grown as per recommended NPK had a mean total carotenoid content of 6.48





T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

mg $100g^{-1}$ which was found to be significantly higher than the one in which farm yard manure (4.66 mg $100g^{-1}$) and neem cake (4.88 mg $100g^{-1}$) were applied. The mean total carotenoid content of vermicompost (8.38 mg $100g^{-1}$) was found to be significantly higher than all the other treatments including T_0 in which recommended NPK was applied.

Variation noticed in the total carotenoid content of amaranthus cultivated using NPK and poultry manure was found to be statistically nonsignificant.

4.2.15. Chlorophyll

The chlorophyll content of amaranthus grown in different treatments varied from 16.58 mg $100g^{-1}$in farm yard manure to 27.35 mg $100g^{-1}$ in vermicompost. The amaranthus grown as per recommended NPK (T_0) had a mean total chlorophyll content of 20.19 mg $100g^{-1}$which was found to be higher than the content observed in amaranthus grown in farm yard manure (16.58 mg $100g^{-1}$), neem cake (17.80 mg $100g^{-1}$) and poultry manure (19.82 mg $100g^{-1}$). The mean total chlorophyll content of amaranthus grown in vermicompost (27.35 mg $100g^{-1}$) was significantly higher than the content observed in $T_{0.}$ However, in T_2 and T_3 the chlorophyll content was found to be significantly low when compared to $T_{0.}$ The effect of different treatments on the chlorophyll content of amaranthus is depicted in Fig.18.

The variation observed in the chlorophyll content of amaranthus grown as per recommended NPK and poultry manure was found to be statistically nonsignificant.

4.2.16. Total phenol

The total phenol in the amaranthus grown under different treatments is given in Table 7 and Fig. 19. The total phenol content ranged between 17.63 mg and 23.93 mg $100g^{-1}$. The lowest content was found in amaranthus grown in neem cake and highest in amaranthus grown in poultry manure. The total phenol content of amaranthus grown in farm yard manure (23.70 mg $100g^{-1}$) and poultry manure (23.93 mg $100g^{-1}$) was

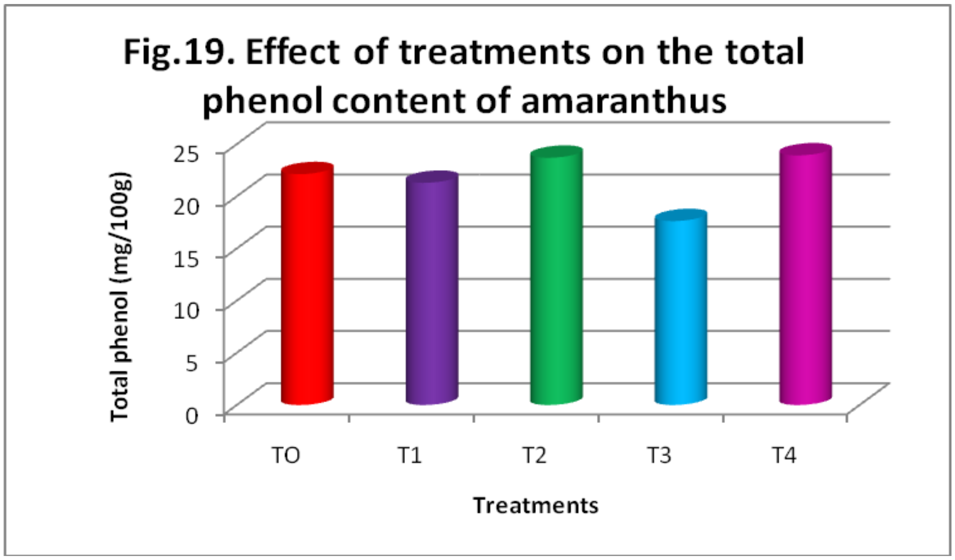


Fig.19. Effect of treatments on the total phenol content of amaranthus

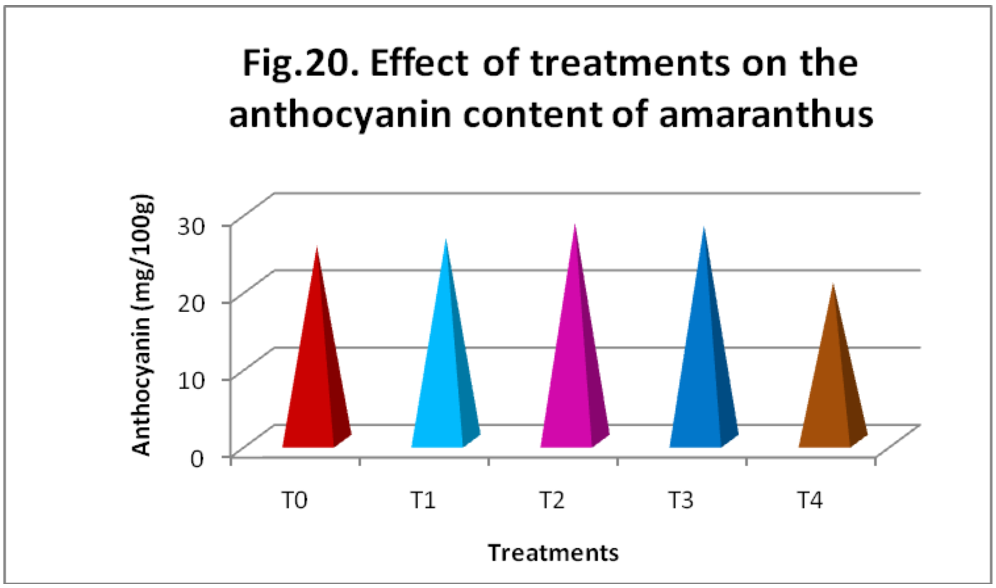


Fig.20. Effect of treatments on the anthocyanin content of amaranthus

T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

Table. 7 Effect of treatments on the carotenoid, chlorophyll, total phenol and anthocyanin content of amaranthus (per 100g)

Treatments		Mean ± SE			
		Carotenoid (mg)	Chlorophyll (mg)	Total phenol (mg)	Anthocyanin (mg)
T_0	Recommended NPK(control)	6.48^{b} ± 0.51	20.19^{b} ±0.32	22.13^{ab}±1.70	25.30^{c} ±0.29
T_1	Vermicompost	8.38^{a} ± 0.53	27.35^{a} ±0.36	21.30^{ab}±1.74	26.33^{b} ±0.32
T_2	Farm yard manure	4.66^{c} ± 0.06	16.58^{c} ±0.79	23.70^{a} ±1.21	28.25^{a} ±0.09
T_3	Neem cake	4.88^{c} ± 0.06	17.80^{c} ±0.10	17.63^{b} ±1.55	27.99^{a} ±0.02
T_4	Poultry manure	6.84^{b} ± 0.03	19.82^{b} ±0.27	23.93^{a} ±1.17	20.53^{d} ±0.06

Values having different superscripts differ significantly

found to be higher than control. However, the increase was statistically nonsignificant. The amaranthus grown as per recommended NPK had a mean total phenol content of 22.13 mg $100g^{-1}$which was found to be higher than the phenol content of amaranthus grown in vermicompost (21.30 mg $100g^{-1}$) and neem cake (17.63 mg $100g^{-1}$). Here also, the variation was found to be statistically nonsignificant.

The variation observed in the total phenol content of amaranthus grown in farm yard manure and neem cake was found to be statistically significant. However, when compared to T_0 the variation observed in the total phenol content of amaranthus grown in different organic manures was found to be statistically nonsignificant.

4.2.17. Anthocyanin

The mean anthocyanin content of amaranthus is given in the Table 7 and Fig. 20. The content of anthocyanin varied between 20.53 mg and 28.25 mg $100g^{-1}$ with the highest and lowest contents in amaranthus grown in farm yard manure and poultry manure respectively. The mean anthocyanin content of amaranthus cultivated in farm yard manure (28.25 mg), vermicompost (26.33 mg) and neem cake (27.99 mg) was found to be significantly higher than control (T_0).

The anthocyanin content of leaves varied significantly between treatments. However, the variation noticed in the anthocyanin content of amaranthus grown in T_2 and T_3 was found to be statistically nonsignificant.

4.3. Antinutritional factors

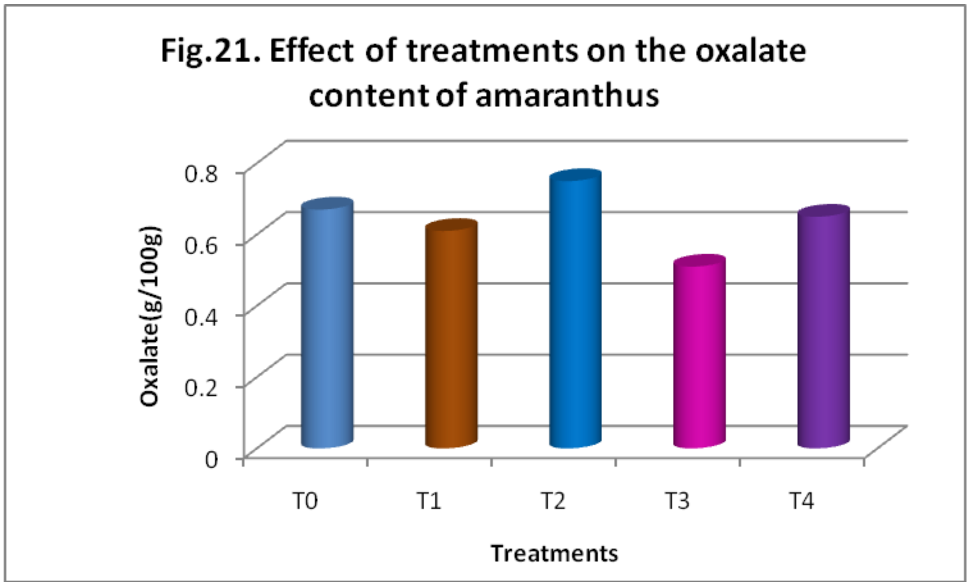
The amaranthus cultivated under different organic treatments were analysed for antinutritional factors namely oxalate and nitrate and compared with the contents in amaranthus cultivated using recommended NPK. The results are furnished in Table 8.

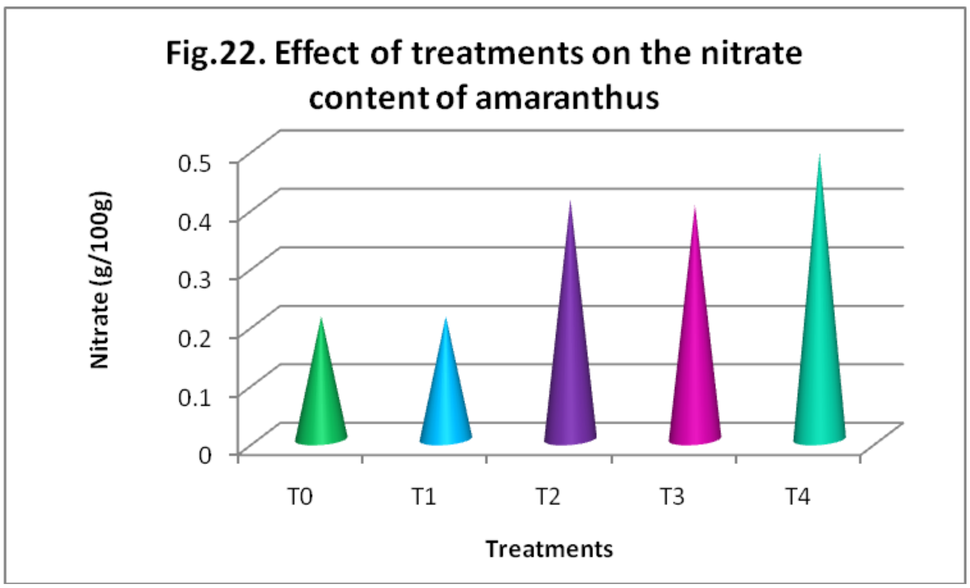
4.3.1. Oxalate

The oxalate content of amaranthus ranged from 0.51 per cent to 0.75 percent (Fig.21). The lowest and highest contents were observed in amaranthus cultivated using neem cake and farm yard manure.

The oxalate content of amaranthus grown using vermicompost, poultry manure and recommended NPK were found to be 0.61 per cent, 0.65 per cent and 0.67 per cent respectively.

Amaranthus grown with farm yard manure with the highest oxalate content varied significantly from the content observed in amaranthus grown under other treatments. The oxalate content of amaranthus grown with recommended NPK was found to be significantly higher than the content observed in amaranthus grown using vermicompost, and neem cake. The oxalate content of amaranthus grown in neem cake was found to be significantly lower than the content observed in other treatments including control.





T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

Table 8. Effect of treatments on the oxalate and nitrate content of amaranthus (per 100g)

Treatments		Mean ± SE	
		Oxalate (g)	Nitrate (g)
T_0	Recommended NPK(control)	0.67^{b} ±0.00	0.21^{c} ±0.00
T_1	Vermicompost	0.61^{c} ±0.00	0.21^{c} ±0.00
T_2	Farm yard manure	0.75^{a} ±0.00	0.41^{b} ±0.01
T_3	Neem cake	0.51^{d} ±0.01	0.40^{b} ±0.00
T_4	Poultry manure	0.65^{b} ±0.00	0.49^{a} ±0.00

Values having different superscripts differ significantly

4.3.2. Nitrate

The nitrate content of amaranthus is presented in the Table 8 and Fig.22 the content varied from 0.21 per cent to 0.49 per cent. The highest nitrate content was found in amaranthus grown using poultry manure and the lowest in the one which was grown as per recommended NPK as well as vermicompost.

Statistically, the nitrate content of amaranthus grown using poultry manure was significantly higher than the nitrate content observed in other treatments. The nitrate content of amaranthus grown in T_0 and T_1 was found to be significantly lower than content observed in other treatments.

4.4. Organoleptic qualities

The organoleptic qualities of amaranthus were assessed by score card method for different quality attributes namely appearance, colour, texture, flavour, taste and overall acceptability. Each of these attributes were scored using nine point hedonic scale by a panel of ten judges. The scores obtained for the amaranthus grown as per recommended NPK were compared with the scores obtained for other treatments namely vermicompost, farm yard manure, neem cake and poultry manure. The mean scores obtained for the organoleptic qualities of cooked amaranthus are presented in Table 9.

The mean scores for appearance (8.3) were found to be high in amaranthus grown in neem cake (T_3) as well as poultry manure (T_4). In amaranthus grown in other treatments namely vermicompost (T_1), farm yard manure (T_2) and recommended NPK (T_0) the mean score was found to be 7.9. The mean rank scores were found to be 2.75, 2.55 and 2.60 respectively for amaranthus grown in vermicompost, farm yard manure and recommended NPK.

For the second quality attribute namely colour, the mean scores ranged from 7.9 to 8.3 with the rank scores in between 2.55 and 3.30. The lowest mean and rank scores were obtained for amaranthus grown in farm yard manure (T_2) and highest in which poultry manure (T_4) was used as the treatment. The amaranthus grown as per recommended NPK (T_0) obtained a mean and rank scores of 8 and 2.75 respectively and was found to be lower than the scores of amaranthus grown in vermicompost (8.2), neem cake (8.1) and poultry manure (8.3).

The scores for texture varied from 7.8 to 8.3 with a mean rank scores in between 2.5 to 3.60. The highest mean and rank scores was obtained for amaranthus grown in poultry manure (T_4) and the lowest in the one which was grown in farm yard manure (T_2). The amaranthus grown as per recommended NPK (T_0) had a mean score of 8 and rank score of 2.85 and was found to be lower than the scores of amaranthus grown in vermicompost (8.1), neem cake (8.1) and poultry manure (8.3).

For flavour, the mean scores varied from 7.4 to 8 with mean rank scores in the range of 2.65 and 3.70. The highest mean and rank scores for flavour was obtained for amaranthus grown using poultry manure followed by farm yard manure (7.6), vermicompost (7.5) and neem cake as well as recommended NPK (7.4).

Table 9. Mean scores for the organoleptic qualities of amaranthus

Treatments	Appearance	Colour	Texture	Flavour	Taste	Overall Acceptability
T_0	7.9 (2.60)	8.0 (2.75)	8.0 (2.85)	7.4 (2.65)	7.9 (3.0)	7.8 (2.75)
T_1	7.9 (2.75)	8.2 (3.35)	8.1 (3.05)	7.5 (2.95)	7.6 (2.55)	7.8 (2.80)
T_2	7.9 (2.55)	7.9 (2.55)	7.8 (2.50)	7.6 (3.00)	7.4 (2.10)	7.7 (2.60)
T_3	8.3 (3.55)	8.1 (3.05)	8.1 (3.00)	7.4 (2.70)	7.9 (3.05)	7.8 (2.85)
T_4	8.3 (3.55)	8.3 (3.30)	8.3 (3.60)	8.0 (3.70)	8.6 (4.30)	8.4 (4.00)
Kendall's W	0.226**	0.082**	0.109**	0.137**	0.386**	0.206**

Figures in parenthesis indicate mean rank scores
** - Significant at 1% level

T_0-Recommended NPK

T_1- Vermicompost

T_2- Farm yard manure

T_3- Neem cake

T_4- Poultry manure

The mean scores for taste of amaranthus grown in organic manures varied from 7.4 to 8.6 with the lowest and highest scores in amaranthus grown in farm yard manure and poultry manure respectively. The mean and rank scores of amaranthus grown under recommended NPK was found to be 7.9 and 3.

For overall acceptability, the mean and rank scores varied from 7.7 to 8.4 and from 2.6 to 4 respectively. Highest mean score was noticed in amaranthus grown using poultry manure (T_4) and lowest in the one which was grown in farm yard manure (T_2).

Overall acceptability of amaranthus grown using recommended NPK (T_0), vermicompost (T_1) and neem cake (T_3) was found to be 7.8 with the rank scores of 2.75, 2.80 and 2.85 respectively.

In the evaluation of different quality attributes using Kendall's test the agreement among the judges was found to be statistically significant.

4.5. Selection of the most desirable treatment

To select the best treatment, among the recommended NPK (T_0), vermicompost (T_1), farm yard manure (T_2) , neem cake (T_4) and poultry manure (T_5) used for the cultivation of amaranth they were ranked on the basis of biochemical and nutritional constituents, antinutritional factors and acceptability of cooked amaranth. The ranking was done relative to the most desirable value for each of the constituents or qualities.

The biochemical and nutritional constituents such as crude fibre, protein, vitamin C, beta carotene, phenol, anthocyanin, calcium, iron, phosphorus, sodium, potassium, magnesium and zinc were ranked relative to the most desirable value for each of the constituent. The details of the constituents along with their ranked order are furnished in Table 10.

For all the biochemical and nutritional constituents the ranking was done in descending order where highest rank of five was given to the highest content for each of the constituent. Since, the antinutritional factors namely oxalates and nitrates are undersirable constituents in green leafy vegetables, the ranking was done in an ascending order where the highest rank of five was given for the lowest content and lowest rank of one was given to the treatment which has high antinutritional content. The details of the antinutritional content with their rank order are given in Table 11.

On the basis of biochemical and nutritional constituents, amaranthus cultivated using farm yard manure was found to be the best for vitamin C, anthocyanin, calcium, sodium, potassium, magnesium and zinc with a rank score of five for each followed by poultry manure with a rank score of five for protein, total phenol and iron.

Table 10. Rank scores for biochemical and nutritional constituents

Treatments	Fibre (g)	Protein (g)	Vitamin.C (mg)	βcarotene (μg)	Phenol (mg)	Anthocyanin (mg)	Calcium (mg)	Iron (mg)	Phosphorus (mg)	Sodium (mg)	Potassium (mg)	Magnesium (mg)	Zinc (mg)
NPK	1.00 (1.00)	2.03 (1.00)	71.25 (1.00)	2282.50 (2.00)	22.13 (3.00)	25.30 (2.00)	242.63 (2.00)	3.25 (1.00)	94.80 (5.00)	9.86 (2.00)	978.05 (4.00)	199.03 (2.00)	0.19 (2.00)
VC	1.25 (2.00)	2.67 (2.00)	78.75 (2.00)	3055.75 (5.00)	21.30 (2.00)	26.33 (3.00)	186.58 (1.00)	4.19 (2.00)	76.29 (1.00)	9.21 (1.00)	954.95 (3.00)	128.45 (1.00)	0.14 (1.00)
FYM	1.63 (4.00)	3.20 (4.00)	95.00 (5.00)	3009.75 (3.00)	23.70 (4.00)	28.25 (5.00)	627.66 (5.00)	5.80 (3.00)	89.85 (4.00)	21.97 (5.00)	984.75 (5.00)	280.90 (5.00)	0.26 (5.00)
NC	2.13 (5.00)	3.14 (3.00)	85.00 (3.00)	3043 (4.00)	17.63 (1.00)	27.99 (4.00)	397.98 (3.00)	7.68 (4.00)	79.86 (2.00)	20.25 (3.00)	705.50 (1.00)	223.88 (3.00)	0.22 (4.00)
PM	1.38 (3.00)	3.63 (5.00)	88.74 (4.00)	2122 (1.00)	23.93 (5.00)	20.53 (1.00)	520.60 (4.00)	8.06 (5.00)	86.03 (3.00)	20.79 (4.00)	726.45 (2.00)	266.78 (4.00)	0.20 (3.00)

Figures in parenthesis are mean rank score

NPK - Recommended NPK
VC - Vermicompost
FYM - Farm yard manure
NC - Neem cake
PM - Poultry manure

Table 11. Rank scores for antinutritional factors

Treatments	Oxalate	Nitrate
Recommended NPK	0.67 (2.00)	0.21 (4.5)
Vermicompost	0.61 (4.00)	0.21 (4.5)
Farm yard manure	0.75 (1.00)	0.41 (2.00)
Neem cake	0.51 (5.00)	0.40 (3.00)
Poultry manure	0.65 (3.00)	0.49 (1.00)

Figures in parenthesis indicate rank order

With respect to antinutritional factors highest score was obtained for recommended NPK and vermicompost for nitrate and neem cake for oxalate.

For organoleptic attributes namely appearance, colour, flavour, texture, taste and overall acceptability the mean rank scores were derived using Kendall's W test. The mean rank scores obtained are given in Table 12. For organoleptic qualities amaranthus cultivated using poultry manure got the highest score for all quality attributes namely appearance, colour, taste, texture, flavour and overall acceptability.

To select the best treatment in the present study, the total score obtained for biochemical and nutritional constituents, antinutritional factors and organoleptic qualities for each treatment were summed up and the details are given in Table 13.

Among the different treatments, amaranthus cultivated using farm yard manure was found to be the best with a total rank score of 75.3. This treatment was found to be the best treatment with respect to biochemical constituents. The second highest total rank score was obtained for amaranthus cultivated using poultry manure with a total rank

Table 12. Rank scores for organoleptic qualities

Treatments	Appearance	Colour	Texture	Flavour	Taste	Overall Acceptability
T_0	2.60	2.75	2.85	2.65	3.00	2.75
T_1	2.75	3.35	3.05	2.95	2.55	2.80
T_2	2.55	2.55	2.50	3.00	2.10	2.60
T_3	3.55	3.05	3.00	2.70	3.05	2.85
T_4	3.55	3.30	3.60	3.70	4.30	4.00

T_0-Recommended NPK T_1- Vermicompost

T_2- Farm yard manure T_3- Neem cake

T_4- Poultry manure

Table 13.Total rank scores for various quality attributes

Treatments	Biochemical constituents	Antinutritional factors	Organoleptic qualities	Grand total
Recommended NPK	28	6.50	16.6	51.1
Vermicompost	26	8.50	17.45	51.95
Farm yard manure	57	3.00	15.3	75.3
Neemcake	40	8.00	18.2	66.2
Poultry manure	44	4.00	22.45	70.45

score of 70.45. This treatment was found to be the best for organoleptic qualities and also had the second highest total score for biochemical constituents.

Discussion

5. DISCUSSION

The study on "Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)" was attempted to assess the physical characters, biochemical and nutritional constituents, antinutritional factors and organoleptic qualities of amaranthus grown using recommended NPK and four different organic manures namely vermicompost, farm yard manure, neem cake and poultry manure.

The discussion pertaining to the study is presented under the following headings.

5.1. Physical characters

5.2. Biochemical and nutritional constituents

5.3. Antinutritional factors

5.4. Organoleptic qualities

5.1. Physical characters

Significant variation in the plant height of amaranthus grown using different treatments was observed in the present study with the maximum height in amaranthus grown in poultry manure followed by farm yard manure. The lowest plant height was noticed in amaranthus grown by the application of recommended NPK. This observation was found to be in line with the studies conducted in capsicum by Cerna (1980) in which the author observed higher vegetative mass, dry weight and plant height by the application of poultry manure. Singh *et al.* (1993) also indicated increased plant height and number of branches per plant in soya bean by the application of farm yard manure along with NPK fertilisers. Anitha (1997) and Dileep (2005) reported significant increase in plant height in chilli by the application of different organic manures. However, contradictory to the findings of the present study, Anwar *et al*. (2001) and Kadir (2002) indicated increased plant height by the application of NPK in broccoli. Improvement in soil physical conditions and available N, P and K in the soil might have enhanced the growth of amaranthus and increased the plant height. Sankar *et al*. (2009) also indicated increased root growth and plant height in onion due to the improvement in the physical conditions and available N, P and K in the soil.

The yield of amaranthus grown using different treatments varied from 6.34 to 20.17 t ha^{-1} with the highest yield in amaranthus grown using poultry manure and lowest in amaranthus grown in neem cake. Studies conducted by Anez and Tavira (1984) and Lu and Bai (1989) reported higher yield in lettuce and cauliflower by the application of poultry manure. An increased yield of 30 per cent for potato, 85 per cent for tomato, 19 per cent for sugar beet, 82 per cent for onion and 64 per cent for spinach by the application of poultry manure was also indicated in the studies conducted by Gardini *et al*. (1992). Higher yield of about 28.18 t ha^{-1} in tomatoes was also noticed by Thamburaj (1994) by the application of poultry manure.

Among the different organic manures, higher yield was observed in amaranthus grown in poultry manure followed by farm yard manure when compared to recommended NPK. Similar to the findings of the present study an higher yield by the use of farm yard manure and poultry manure in crop production was reported (Anon., 1991). However, contradictory to the present finding Anitha and Prema (2003) observed significantly higher yield in tomato due to the application of vermicompost.

Espitiru *et al*. (1995) attributed the presence of both readily available and slow release nitrogen due to addition of poultry manure as the reason for yield improvement. Krochmal and Samuels (1970) found that increased number of leaves produced more photosynthates and yield in cabbage. Anitha (1997) reported that application of poultry manure in chilli resulted in production of more photosynthates and an improvement in the yield.

As reported by Balasubramanian *et al*. (1972) organic manures especially farm yard manure which had large population of bacteria, actinomycetes and fungi might have stimulated the microorganisms those already present in the soil and thereby increased the yield. The application of organics might also have increased nitrogen fixation and phosphorus solubilisation in the soil due to improved microbiological activity in organically amended soils especially with the use of farm yard manure and poultry manure. Thus, the humus in soil characteristics might have ultimately increased the yield.

Various studies conducted in celery, lettuce and leek (Bohec, 1990) as well as in hyacinth bean (Noor *et al.*, 1992) have also indicated an increased yield by the application of farm yard manure.

Increased yield and plant height observed in amaranthus cultivated using most of the organic manures might be due to the improvement in the physical characteristics of the soil like aeration, permeability, aggregation, water and nutrient holding capacity of the soil as suggested by Banerjee (1998).

The days to flowering of amaranthus grown in different treatments varied from 93.50 to 125.75 days. Late flowering which is considered as a desirable trait in amaranthus was observed in the treatment of amaranthus grown in poultry manure followed by farm yard manure and neem cake. Early flowering was observed in amaranthus grown in vermicompost. However, Rekha (1999) and Krishna (2005) observed early flowering by the application of poultry manure in brinjal and cowpea respectively in which early flowering is considered as the desirable criteria. However, Kumaran *et al*. (1998) reported earliness in flowering by five days due to application of farm yard manure and inorganic fertiliser in tomato. Significant reduction in flowering period of cauliflower cultivated in vermicompost was indicated by Nath and Singh (2011) as observed in amaranthus cultivated using vermicompost in the present study.

Studies conducted by Preetha (2003) and Thankamony (2005) reported higher yield with vermicompost application. The lower yield of 7.16 t ha^{-1} observed in the present study in vermicompost application can be attributed to the early flowering which reduced the number of harvests and yield.

5.2. Biochemical and nutritional constituents

Amaranthus grown under vermicompost had the highest moisture content of 86.55 per cent followed by recommended NPK (84.95 %), neem cake (77.50 %), poultry manure (74.95 %) and farm yard manure (74.75 %).

As observed in the present study, Dominguez and Edwards (1977); Hoitink (1980); Tomati *et al.* (1988); Alvarez *et al.*(1995) and Shivaputra *et al*. (2004) indicated high moisture content in plants grown using vermicompost and attributed that this could be due to retention of moisture by the application of vermicompost.

Significant variation was observed between the protein content of amaranthus grown in different organic manures and recommended NPK. The protein content of amaranthus grown organically were found to be significantly high than the amaranthus grown as per recommended NPK. Among the organic manures, wide variation was not observed in the protein content of amaranthus grown with farm yard manure and neem cake. Amaranthus grown in poultry manure was found to be having maximum protein content of 3.63 per cent. This findings was in accordance with the findings reported by Joseph (1998) in snake gourd, Kumar (2007) in knol-khol, Singh (2007) in tomato and Singh (2011) in okra in which the authors reported high protein content in plants cultivated using poultry manure. The high protein content observed by the application of poultry manure might be due to the release of nitrogen from poultry manure as uric acid which is readily available to plants. The significant increase in the protein content of amaranthus cultivated using organic manures might be due to the increased nitrogen fixation in the soil due to increased microbiological activity in the organically amended soils.

The protein content of amaranthus cultivated using organic manures and recommended NPK was found to be almost similar to the protein content of 3.03 per cent noticed in *Amaranthus tricolor* L. during summer season by Mathew (2000). However, Gopalan *et al*. (1989) indicated a high protein content of 4 per cent in tender *Amaranthus gangeticus*. Suman (2000) also indicated 4 per cent protein in amaranthus.

The crude fibre content of amaranthus cultivated using different organic manures was found to be higher than the amaranthus grown in recommended NPK. The crude fibre content of amaranthus grown using different treatments varied from 1.00 per cent to 2.13 per cent with the highest content in amaranthus grown in neem cake and lowest in which recommended NPK was used. The fibre content noticed in amaranthus was found to be in line with the content observed by Easwaran and Goswani (1989); Saikia and Shadeque (1994) and Gopalan *et al*. (1989) for various leafy vegetables. Mathew (2000) also indicated a fibre content of 1.72 g per 100g in *Amaranthus tricolor* L which was found to be lower than the content observed in amaranthus grown with neem cake and higher than the amaranthus grown using different treatments including NPK. However, Gopalan *et al*. (1989) indicated a crude fibre content of 1 per cent in tender *Amaranthus gangeticus* which was found to be similar to the fibre content of amaranthus grown in recommended NPK. The crude fibre content of amaranthus grown in different organic manures was found to be higher than the fibre content of 1 per cent observed in *Amaranthus gangeticus* (Gopalan *et al*., 1989). As revealed in the present study, Joseph (1998) also indicated high fibre content in snake gourd cultivated using organic manures.

The starch content of amaranthus cultivated from different treatments varied from 0.23 per cent to 0.55 per cent with the lowest and highest content in amaranthus grown using vermicompost and poultry manure respectively. The starch content observed in amaranthus cultivated using different treatments was found to be in line with the starch content reported in amaranthus by Wills *et al*. (1984) and Suman (2000). Mathew (2000) also indicated a starch content of 0.20 per cent in *Amaranthus tricolor* during summer season. However, John *et al*. (1987) indicated a slightly high starch content of 0.73 per cent in *Amaranthus tricolor*.

In the present study, the starch content of amaranthus cultivated using organic manures like farm yard manure, neem cake and poultry manure was found to be almost similar to the starch content noticed in amaranthus cultivated using recommended NPK. But, in the case of amaranthus grown in vermicompost, the starch content was found to be significantly lower than all other treatments including the one which was grown with recommended NPK.

Amaranthus cultivated in farm yard manure had the highest vitamin C content of 95 mg $100g^{-1}$ and was found to be significantly higher than the vitamin C content of amaranthus cultivated using recommended NPK. However, the variation observed in the vitamin C content of amaranthus grown using different organic manures was found to be statistically insignificant and varied from 78.75 mg to 88.75 mg $100g^{-1}$. When compared to the vitamin C content of amaranthus cultivated in NPK, the amaranthus cultivated in organic manures had high vitamin C. Singh (2011) also indicated significantly high vitamin C in okra cultivated organically when compared to conventional treatments. The vitamin C content of amaranthus grown in different treatments was found to be lower than the vitamin C content of amaranthus observed by Gopalan *et al*. (1989) in *Amaranthus gangeticus* and Mathew (2000) and Suman (2000) in *Amaranthus tricolor*. Very low vitamin C content observed in amaranthus cultivated using recommended NPK and vermicompost might be due to the high moisture content observed in these treatments as suggested by Williams (2002) in which the author ascribed higher water content in conventionally grown foods as the reason for low vitamin C content. Woese *et al.* (1997) also indicated high vitamin C content in organically grown potatoes and vegetables particularly leafy vegetables. The higher vitamin C content observed in amaranthus grown organically especially farm yard manure, poultry manure and neem cake could also be correlated with lower water content of organic produce. Lampkin (1990) also indicated high vitamin C in organic vegetables.

Omori and Ogura (1972) obtained improved fruit quality in terms of vitamin C by the application of farm yard manure, compost and oil cakes in vegetables like tomato, onion, gourds, chinese cabbage and chilli. High vitamin C content in *Solanum villosum* by the application of farm yard manure was also reported in the studies conducted by

Kipkosgei *et al*. (2003). Ravishankar *et al.* (2008) also noticed maximum ascorbic acid in lettuce by the application of farm yard manure.

Amaranthus cultivated in vermicompost had the highest beta carotene content of 3055.75 µg $100g^{-1}$ which was found to be almost similar to the content observed in amaranthus cultivated using farm yard manure and neem cake. The beta carotene content of amaranthus grown in vermicompost, farm yard manure and neem cake was found to be significantly higher than the content observed in amaranthus cultivated with recommended NPK. However, the content of T_4 (poultry manure) was significantly lower than the content noticed in T_0. But, Eggert and Kahrmann (1984) and Woese *et al*. (1997) reported no difference in the beta carotene content of organically and conventionally fertilised carrots and vegetables. Salomon (1972) also did not observe any variation in the carotene content of carrots fertilised with organic and mineral fertiliser. However, Evers (1989) and Leclerc *et al.* (1991) indicated high beta carotene in carrots cultivated organically as was observed in the present study in amaranthus cultivated with vermicompost, farm yard manure and neem cake.

Mathew (2000) indicated a very high beta carotene in *Amaranthus tricolor*. But, Hyder (2004) indicated a lower beta carotene in the range of 340.5 to 1879.41 µg $100g^{-1}$ in green leafy vegetables. The variation observed might be due to the difference in the leafy vegetables and the cultivation practices.

Regarding the mineral content of amaranthus cultivated using different treatments, it was seen that all minerals except phosphorus and iron were high in amaranthus cultivated with farm yard manure. In the case of phosphorus, highest phosphorus content was noticed in amaranthus cultivated in recommended NPK and was found to be on par with the one which was cultivated using farm yard manure. In the case of iron, the amaranthus cultivated using organic manures had high iron content when compared to T_0. Among the organic manures also highest iron content was found in the amaranthus which was cultivated using poultry manure. Thus, it could be concluded that organic manures significantly improved the mineral content of amaranthus. The organic manures might have increased the absorption from the soil and improved the mineral content. The increase mineral content observed in amaranthus cultivated organically might be due to availability and mobility of micronutrients in soil from organic manures and their uptake by amaranthus and onion as suggested by Qingren *et al*. (2009) and Chattoo *et al*. (2009). Various studies have indicated that organic manures improve the physical properties of soil like moisture retention, water absorption, aeration and soil texture leading to improvement in the nutrient content. Here, organic manures might have provided minerals at optimum levels as suggested by Sharma *et al*. (2000) and improved their efficiency. But, Woese *et al*. (1997) did not observe any difference in the mineral or trace element levels of organically or conventionally grown vegetables. However, Singh (2011) indicated high calcium, magnesium, manganese, zinc, iron and copper in okra which received organic treatment.

The carotenoid content of amaranthus varied from 4.66 mg to 8.38 mg $100g^{-1}$ with the highest and lowest carotenoids in amaranthus cultivated using vermicompost and farm yard manure respectively. Prakash *et al*. (1993) reported that carotenoid content of *Amaranthus hypochondriacus*, *Chenopodium auinoa* and celosia varied from 9 to 20 mg $100g^{-1}$. The carotenoid content obtained in the present study was found to be lower than the values reported by the authors. This variation might be due to the difference in the species of amaranthus used for the study. Among the different organic manures, the amaranthus cultivated using vermicompost obtained a high carotenoid content. But, Mujahid and Gupta (2010) reported a lower carotenoid content in the range of 3.43 to 3.88 mg $100g^{-1}$ in lettuce by the application of vermicompost. The carotenoid content of amaranthus grown in recommended NPK varied significantly from the carotenoid content of amaranthus grown in different organic manures except the one which was grown in poultry manure. The carotenoid content of amaranthus grown in recommended NPK and poultry manure was found to be almost similar.

Total chlorophyll content of amaranthus grown in different treatments varied from 16.58 mg in farm yard manure to 27.35 mg $100g^{-1}$ in vermicompost. The chlorophyll content in amaranthus cultivated using vermicompost was found to be significantly higher than all other treatments. Shivaputra *et al.* (2004); Sanwal *et al.* (2007) and Singh (2011) reported an increase in the chlorophyll content of plants treated with organic manures. The high chlorophyll content observed in amaranthus grown in vermicompost might be due to the accumulation of nutrients especially micronutrients in leaf tissues which in turn might have ensured the photosynthetic efficiency causing more synthesis and accumulation of chlorophyll as suggested by Gathala *et al*. (2007). The chlorophyll content of T_2, T_3 and T_4 was found to be lower than the content observed in T_0. Wide variation was noticed in the chlorophyll content of amaranthus cultivated using different treatments.

Total phenols in amaranthus grown using different treatments ranged between 17.63 mg to 23.93 mg $100g^{-1}$. The lowest content was found in amaranthus grown in neem cake and highest in amaranthus grown in poultry manure. Hyder (2004) reported a total phenol content in the range of 11.97 to 49.71 mg 100^{-1} in leafy vegetables. Francisco *et al.* (2008) also indicated high levels of phenolic compounds in sweet pepper grown using poultry manure. The variation observed in the total phenol content of amaranthus cultivated using different treatments was found to be statistically insignificant when compared to recommended NPK.

Anthocyanin content of amaranthus grown in different treatments varied from 20.53 mg in poultry manure to 28.25 mg $100g^{-1}$ in farm yard manure. The anthocyanin content of amaranthus cultivated using farm yard manure and neem cake was found to be significantly higher than all other treatments. Studies conducted by Grusak and DellaPenna (1999); Dixon (2001) and Asami *et al*. (2003) found that anthocyanin compounds are high in crops cultivated organically when compared to those grown under non-organic condition.

5.3. Antinutritional factors

The oxalate content of amaranthus grown using different treatments varied from 0.51 to 0.75 per cent. The lowest and highest oxalate content were observed in amaranthus cultivated using neem cake and farm yard manure respectively. Thamburaj *et al.* (1994) reported an oxalate content in the range of 0.3 to 1.92 per cent on dry weight basis in different leafy vegetables. Kumaran (2003) reported an oxalate content in the range of 0.004 to 2.97 per cent in the unconventional leafy vegetables like tamarind, ponnaviram, mint, coriander, pisonia, cowpea, pumpkin, colocasia and burmese coriander. However, Mziray *et al.* (2001) indicated a very high oxalate content in the range of 3.38 to 4.33 per cent in *Amaranthus hybridus* when compared to the content observed in the present study.

Lowest nitrate content was observed in amaranthus cultivated using recommended NPK and vermicompost. In farm yard manure, neem cake and poultry manure the nitrate content was found to be significantly higher when compared to T_0 and T_1. Woese *et al.* (1997) reported high nitrate levels in green leafy vegetables grown under conventional conditions when compared to organic conditions. Vogtmann *et al*. (1993) also indicated significantly high nitrate for NPK applied leafy vegetables than for compost. However, Worthington (1998) indicated either increased or same levels of nitrates in fruits and vegetables cultivated organically when compared to conventionally grown crops.

5.4. Organoleptic qualities

The organoleptic evaluation indicated high acceptability for all the quality attributes in amaranthus cultivated organically and conventionally. A mean score of above 7 was obtained for appearance, colour, flavour, texture, taste and overall acceptability for amaranthus cultivated with different organic manures and NPK. However, among the different treatments, amaranthus cultivated using poultry manure obtained the maximum scores in the range of 8.0 to 8.6 for the six quality attributes. The mean rank scores of T_4 was also found to be high when compared to other treatments. In the present study, amaranthus grown in organic and conventional systems were found to be acceptable. This findings was found to be in line with the observations noticed by DeEll and Prange (1992) and Caussiol and Joyce (2004) in which the authors did not observe any consistent variation in the acceptability of organically and conventionally grown fruits and vegetables. Gennaro and Quaglia (2003) reported that organically grown okra soup produce more colour, taste, texture and flavour. Patel *et al.* (2009) reported better taste in organic vegetables when they were grown in farm yard manure. Rembialkowska (2003) and Saba and Messina (2003) also indicated better taste and smell with good shelf life in organic crops.

Among the different treatments, amaranthus cultivated in farm yard manure was found to be the best on the basis of various quality attributes followed by poultry manure. The amaranthus cultivated using NPK obtained the lowest total rank score. Thus, the amaranthus cultivated using organic manures was found to be better for various quality attributes.

Summary

6. SUMMARY

The study entitled ‘Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)’ was undertaken to evaluate the effect of different organic manures on the physical characters, biochemical and nutritional constituents, antinutritional factors and organoleptic qualities of amaranthus. Amaranthus was grown with four different organic manures namely vermicompost, farm yard manure, neem cake and poultry manure. They were compared with amaranthus cultivated by applying recommended NPK which was taken as the control.

Amaranthus (cv. Arun) leaves from the project on ‘Trial on organic production of amaranth’ in the All India Coordinated Research Project (VC) were collected during the summer season of Feb – April, 2010. Amaranthus cultivated from different treatments at their edible stage were collected for the study. The quantity of organic manures used in each treatment was equivalent to 100 per cent recommended nitrogen.

Amaranthus cultivated using poultry manure (T_4) had increased plant height (130.30 cm), maximum yield (20.17 t/ha) and was late flowering (125.75 days) when compared to all other treatments. The appearance of amaranthus cultivated with recommended NPK, farm yard manure and poultry manure was good. The colour of amaranthus grown with different organic manures as well as recommended NPK was found to be maroon red.

The moisture content varied from 74.75 per cent to 86.55 per cent with amaranthus grown using vermicompost having the highest moisture content.

The protein content of amaranthus varied from 2.03 per cent to 3.63 per cent with the highest content in amaranthus grown in poultry manure and the lowest in amaranthus grown in recommended NPK.

The crude fibre content varied from 1.00 per cent (recommended NPK) to 2.13 per cent (neem cake). The highest and lowest starch content was found in amaranthus cultivated with poultry manure and vermicompost respectively with the values ranging from 0.23 per cent to 0.55 per cent.

The vitamin C content ranged from 71.25 mg to 95 mg $100g^{-1}$ with amaranthus cultivated using farm yard manure having the highest value and the lowest value was observed in amaranthus grown using recommended NPK while the beta carotene ranged from 2122 µg $100g^{-1}$ in amaranthus grown in poultry manure to 3055.75 µg $100g^{-1}$ in amaranthus grown in vermicompost.

Among the macrominerals namely calcium, phosphorus, sodium, potassium, and magnesium highest content was observed in amaranthus grown with farm yard manure except in the case of phosphorus. Highest phosphorus was noticed in amaranthus grown with recommended NPK (94.80 mg $100g^{-1}$). Amaranthus cultivated using vermicompost got lowest value for calcium (186.58 mg $100g^{-1}$), phosphorus (76.29 mg $100g^{-1}$), sodium (9.21mg $100g^{-1}$) and magnesium (128.45 mg $100g^{-1}$). Lowest potassium content was observed in amaranthus grown with neem cake (705.5 mg $100g^{-1}$).

Among the micronutrients, highest iron (8.06 mg $100g^{-1}$) and zinc (0.26mg$100g^{-1}$) content was observed in amaranthus grown using poultry manure and farm yard manure and lowest was observed in amaranthus cultivated using recommended NPK (3.25 mg $100g^{-1}$) and vermicompost (0.14 mg $100g^{-1}$) respectively.

Total carotenoids and total chlorophyll content varied from 4.66 mg to 8.38 mg $100g^{-1}$ and 16.58 mg to 27.35 mg $100g^{-1}$ respectively. The total phenol content varied between 17.63 mg and 23.93 mg $100g^{-1}$ with the lowest content in amaranthus grown in neem cake and highest in amaranthus grown in poultry manure. Anthocyanin content of amaranthus varied between 20.53 mg and 28.25 mg $100g^{-1}$ with the highest and lowest content in amaranthus grown in farm yard manure and poultry manure respectively.

The antinutritional factors like oxalates and nitrates in the leaves also were analysed. The lowest percentage of oxalate was noticed in amaranthus cultivated using neem cake (0.51 per cent) where as the nitrate was found to be low in amaranthus grown with recommended NPK (0.21 per cent) and vermicompost (0.21 per cent).

The acceptability of the amaranthus was assessed after cooking at laboratory level by a panel of selected judges using score card. The appearance, colour, flavour, texture, taste and overall acceptability were evaluated by score card containing 9 point hedonic scale. Amaranthus cultivated using organic manures and recommended NPK was found to be organoleptically acceptable. Comparatively, highest mean scores for different organoleptic qualities were noticed in amaranthus grown with poultry manure.

The most desirable treatment was selected on the basis of biochemical and nutritional constituents, organoleptic qualities and low antinutrient content. Among the different treatments, amaranthus cultivated using farm yard manure was found to be the best for various quality attributes with a total rank score of 75.3 followed by poultry manure (70.45). Amaranthus cultivated using NPK obtained the lowest total rank score. Thus, amaranthus cultivated using organic manures was found to be better for various quality attributes.

However, to obtain a conclusive result, the nutrient composition of inputs used for the study as well as the uptake of nutrients by amaranthus and their seasonal variation should be taken up.

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*Originals not seen

Appendix

APPENDIX I

Score card for organoleptic evaluation of cooked amaranth

Name of the judge:
Date :

Characteristics	**Score**				
	1	**2**	**3**	**4**	**5**
Appearance					
Colour					
Flavour					
Texture					
Taste					
Over all acceptability					

9 point Hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature:

QUALITY EVALUATION IN ORGANIC AMARANTHUS (*Amaranthus tricolor* L.)

By

APARNA, T.

(2009-16-101)

Abstract

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Home Science

(FOOD SCIENCE AND NUTRITION)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF HOME SCIENCE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR-680 656

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ABSTRACT

The study entitled 'Quality evaluation in organic amaranthus (*Amaranthus tricolor* L.)' was undertaken to evaluate the effect of different organic manures on the physical characters, biochemical and nutritional constituents, antinutritional factors and organoleptic qualities of amaranthus. Amaranthus were grown with four different organic manures namely vermicompost, farm yard manure, neem cake and poultry manure. They were compared with amaranthus cultivated by applying recommended NPK which was taken as the control.

Edible leaves of amaranthus (cv. Arun) cultivated under the All India Co-ordinated Research Project (VC) in the Department of Olericulture were collected for the study. The quantity of organic manures used in each treatment was equivalent to 100 per cent recommended nitrogen.

Amaranthus cultivated using poultry manure had increased plant height (130.30 cm) and maximum yield (20.17 t/ha) and was late flowering (125.75 days). The appearance of amaranthus cultivated with NPK, farm yard manure and poultry manure was found to be good with maroon red colour.

The leaves of amaranthus were analysed for various biochemical and nutritional components. Amaranthus cultivated using vermicompost had the highest moisture, beta carotene, carotenoids, and chlorophyll. The protein and starch were found to be maximum in amaranthus grown with poultry manure. Amaranthus cultivated with recommended NPK had the lowest fibre and protein content.

Application of farm yard manure helped to improve the mineral content in amaranthus, in which maximum levels of calcium, sodium, potassium, magnesium and zinc were observed. Maximum iron content was noticed in amaranthus cultivated using poultry manure where as phosphorus was maximum in amaranthus grown with

recommended NPK. Lowest mineral content was noticed in amaranthus cultivated using vermicompost.

Anthocyanin and vitamin C were also found to be high in amaranthus cultivated using farm yard manure. Lowest content of vitamin C was noticed in amaranthus grown with recommended NPK.

The antinutritional factors in amaranthus were also evaluated. Low levels of nitrates and oxalates are considered as desirable in green leafy vegetables. The lowest percentage of oxalate was noticed in amaranthus cultivated using neem cake where as the nitrate was found to be low in amaranthus grown with recommended NPK and vermicompost.

Amaranthus cultivated using organic manures and recommended NPK was found to be organoleptically acceptable. Comparatively, highest mean scores for different organoleptic qualities were noticed in amaranthus grown with poultry manure.

Among the different treatments amaranthus cultivated using farm yard manure was found to be the most ideal treatment for various quality attributes followed by poultry manure.