7.4.9. ***Amaranthus spinosus*** L., Sp. Pl., ed. 1, 991 (1753); Boulos, Fl. Egypt 1: 132 (1999).

Proximate Composition and Proteins

Amaranthus spinosus was reported rich in crude protein, but generally poor in basic amino acids (Singh and Rakib, 1971). However, the leaves have the best amino acid composition compared with leaves of *Coriandrum sativum*, *Mentha spicata*, *Spinacia oleracea*, *Trigonella foenum-graecum*, and *Basella rubra* (Vasi and Kalintha, 1980). Total protein in 8 leafy vegetable plants (*Portulaca oleracea*, *Portulaca quadrifida*, *Amaranthus spinosus*, *Mentha spicata*, *Coriandrum sativum*, *Trigonella foenum-graecum*, *Basella rubra*, and *Spinacea oleracea*) ranged from 29.0 to 7.9% (on a dry wteight basis) in decreasing order of the list above (Mirajkar *et al*., 1984). The amino acids identified on pollen grains of 19 plants (including *Amaranthus spinosus*) were cystine, lysine, histidine, asparagine, arginine, glycine, glutamic acid, alanine, proline, tyrosine, and tryptophan (Barua and Sarma, 1984).
The protein and oil in 6 species of *Amaranthus* (including *Amaranthus spinosus*) were 12.6 - 17.5 % and 3.5 - 5.7 % respectively. The amount of carotenoids ranged 11.7-18.7 (mg/100g), vitamin C 106-179 (mg/100g), protein 1.4-4.3%, nitrate 0.46-0.87% and oxalate 0.84-1.42% (Prakash *et al*, 2001). The contents of crude protein, crude fat, dietary fiber, total sugar and ash content of the plant were also reported by Zhang *et al*. (2001). A ribosome inactivating protein named amaramangin is isolated from *Amaranthus* (comprising *Amaranthus spinosus*) seeds. The protein has molecular weight of 29 kDa and isoelectric point greater than 9 (Chen *et al*., 2004). The seeds of *Amaranthus spinosus* contain 17% protein (Srivastava and Roy, 2012). The protein and carbohydrates of the leaves are 9.00±0.19 and 21.29±1.63 (mg/100g fresh weight) respectively (Srivastava, 2011). Other date on the proximate composition are shown in Tables 13 and 26.

The study of the free amino acids of *Amaranthus spinosus* revealed the presence of alanine, serine, tryptophan, valine and leucine (Behari and Andhiwal, 1976a,b). The nutritive value of certain weed species during the dry season was studied by Nuwanyakapa *et al*. (1983). They reported that during the dry season, cattle were reluctant to graze the increasingly fibrous and protein-deficient cultivated forages, so they consumed *Amaranthus spinosus*, despite its very spiny texture. Therefore, they recommended that *Amaranthus spinosus* should not be removed from pasture during the dry season.

Iron, Ca, β-carotene, ascorbic acid (vitamin C) and oxalic acid contents of the plant have been reported by several authors (e.g. Rangarajan and Kelly, 1998; Prakash *et al*., 2001; Rajyalakshmi *et al*., 2001; Steyn *et al*., 2001; Kowsalya, 2002; Rao and Vijay, 2002; Lyimo *et al*., 2003; Qiu and Zeng, 2004; Sengupta and Baskaran, 2009; Nakafamiya *et al*., 2010). Vitamin B_2 and C contents were reported high (Zhang *et al*., 2001). Vitamin E (α-tocopherol) was also detected in the plant (Ching and Mohamed, 2001).

Singh *et al*. (1993) purified a lectin from *Amaranthus spinosus*. The lectin is a dimeric protein composed of subunits having molecular weight of 37,000 k Da, held together by disulphide linkages. The lectin is non specific and reacted with human and various animal erythrocytes. It is a glycoprotein having no metal ion requirement for its activity.

Amaranthus spinosus has a high Ca content (0.47 %). In spite of a fairly high oxalic acid content, its Ca was as well utilized as milk (Devadatta and Appanna, 1954). Ash from the plant contains 31 % of soluble K salts and can form satisfactory a potential source of potash (Prasad and Dange, 1947). According to Odhav *et al*. (2007) the plant contains mineral concentrations exceeding 1% of plant dry weight, and are much higher than mineral concentrations in conventional edible leafy vegetables. Among six non conventional leafy vegetables consumed by rural populace in Nigeria, *Amaranthus spinosus* leaves contain the highest level of iron (38.4 mg/100 g dry weight) (Barminas *et al*., 1999). The mineral content

of the leaves is Na, 30.00±1.52; K, 2500±0.50; Ca, 4500±0.93; and Fe, 13.28±0.81 (mg/100g dry weight) (Srivastava, 2012). The trace metal contents of leaf and stem were in the order Fe > Mn > Zn > Cu > Cr > Ni > Pb. The contentrations of these metals appeared to be within the safe limits of human consumption (Olowoyo *et al*., 2012). However the plant is a potential agent (phytoremediation) for heavy metal accumulation (Chinmayee *et al*., 2012). The nutritional evaluation of the plant has been reported by others (e.g. Kowsalya and Indra, 2010; Adewolu and Adamson, 2011; Srivastava, 2011).

Pharmacognostical studies of the different parts of the plant have been reported (Chumbhale *et al*., 2009; Jhade *et al*., 2009, 2011a; Mathur *et al*., 2010; Baral *et al*., 2011; Mishra *et al*., 2011; Sangameswaran *et al*., 2011)

Lipids

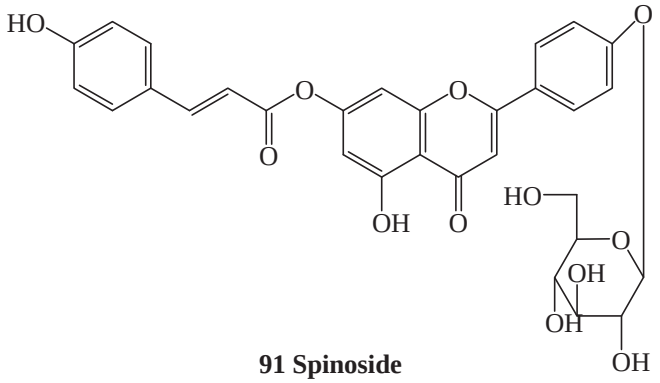
The seeds of several plant species, including *Amaranthus spinosus*, were reported as good sources of unsaturated fatty acids which accounted for > 50 of the glyceride mixed fatty acids (Ahmad *et al*., 1979). The fatty acids of the plant are shown in Tables 19 and 23.

Amaranthus spinosus contains *n*-alkanes C_{23}-C_{33} and iso (-2-methyl)-alkanes C_{29}-C_{33}; esters which were transesterified and resolved into acids C_{18}-C_{32} (as Me esters) and free alcohols C_{20}-C_{26}; aliphatic alcohols C_{10}-C_{32}; sterols (β-sitosterol, stigmasterol, campesterol, and cholesterol), and free acids C_4-C_{32} (C_{18} group contained stearic, oleic, and linoleic acids) (Behari and Andhiwal, 1976b).).

The following sterols were identified from the herb: β-sitosterol, stigmasterol, campesterol, cholesterol (Behari and Andhiwal, 1976a,b), α-spinasterol (Banerji and Chakravarti, 1973; Abdul Aziz *et al*., 2006), β-sitosterol glucoside (Azhar-ul-Haq, 2004), and stigmasterol glycoside (Azhar-ul-Haq, 2006). α-Spinasterol octacosanoate was isolated from the roots (Banerji, 1979). Hentriacontane (Banerji and Chakravarti, 1973) and 1-nonadecanol (Abdul Aziz *et al*., 2006) were also isolated from the plant.

Phenolics and Other Constituents

Kaempferol 3-*O*-rutinoside as ingredient responsible for sunscreen activity of the plant (Lai *et al*., 1997), rutin (1.9 %) and spinoside (**91**, 7-*p*-coumaroyl apigenin-4'-*O*-β-D-glucopyranoside) (Azhar-ul-Haq *et al*., 2004) were isolated from the whole plant. *Amaranthus spinosus* contains the following phenolic acids and flavonoids: hydroxycinnamates, caffeoylquinic acid, coumaroylquinic acid, feruloylquinic acid, quercetin diglycoside, quercetin 3-*O*-rutinoside, quercetin 3-*O*-glucoside and kaempferol diglycoside. The amounts of these compounds are 305 mg/100 g (Stintzing *et al*., 2004). The presence of rutin and quercetin has been also reported by others (Miean and Mohamed, 2001; Kumar *et al*., 2008a; Suryavanshi *et al*., 2008). The concentration of rutin in the whole plant powder was found to be 0.15 % (Suryavanshi *et al*., 2007).



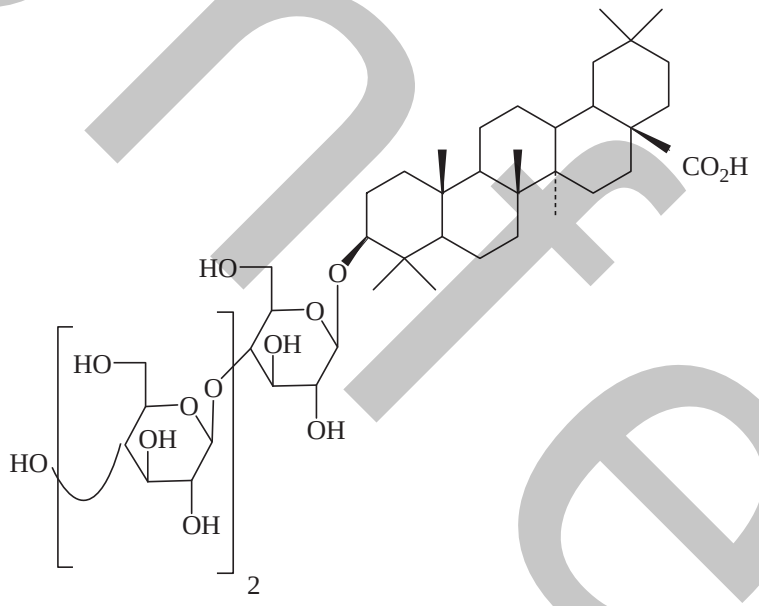
91 Spinoside

The plant contains amaranthoside, a lignan glycoside, amaricin (a coumaroyl adenosine) (Azhar-ul-Haq, 2006), α-xylofuranosyl uracil and β-D-ribofuranosyl adenine (Azhar-ul-Haq, 2004). Glycinebetaine and trigonelline were identified in *Amaranthus spinosus* (Table 35) (Blunden *et al*., 1999). The betacyanins in the plant were identified as amaranthine, isamaranthine, betanin and isobetanin (Stintzing *et al*., 2004).

A saponin mixture has been isolated from the roots. The genin part was oleanolic acid, and D-glucose and D-glucuronic acid were identified as sugar moieties (Banerji and Chakravarti, 1973). Three other saponins have been identified from the roots *viz.*β-D-glucopyranosyl-(1→4)-β-D-glucopyranosyl-(1→4)-β-D-glucopyranosyl-(1→3)-oleanolic acid (**92**) (Banerji, 1979), β-D-glucopyranosyl-(1→2)-β-D-gluco-pyranosyl-(1→2)-β-D-glucopyranosyl-(1→3)-α-spinasterol and β-D-glucopyranosyl-(1→4)-β-D-glucopyranosyl-(1→3)-α-spinasterol (Banerji, 1980).

The leaves have been reported to contain anthaquinone derivatives, cardiac glycosides and saponins (Kumar *et al.*, 2012b).

Dabho'kar (1959) studied the buffer-index of the root sap of *Amaranthus spinosus* and found that it can be considered as indicator of slightly alkaline soils, in addition to its role as indicator of soil rich in N. The variations of the acidity in the plant were described (Bharucha and Shankar, 1953). The biosorption of Cu^{2+} in aqueous solutions by *Amaranthus spinosus* roots has been stated useful for treating waster water containing trace amounts of copper ions



92

(Chen *et al*., 1996).). The studies of biochemical monitoring of sewage pollution by Sundararajan *et al*. (1994) revealed that responses in enzyme activity in plants exposed to sewage pollution vary with species. Variation in enzyme activity under such conditions can serve as a biochemical monitoring tool for pollution toxicity. Significant reduction was observed in nitrate reductase activity in all species examined that were subjected to sewage stress. Status of this enzyme can be best used as a sewage pollution indicator. However increased activity in polyphenol oxidase and ascorbic acid oxidase occurs in plants exposed to sewage pollution. *Amaranthus spinosus* qualifies itself biochemically to be a sensitive species of sewage pollution. The importance of selected species of Amaranthaceae (*Amaranthus spinosus*, *Alternanthera philoxeroides* and *Alernanthera sessilis*) for their

bioremediation potential, capacity to bioconcentration of essential and non-essential elements from biosolid- and sewage-contaminated sites, aggressive colonizing capability on biosolids and sewage sludge, and concomitant nutritional implications are highlighted by Prasad (2001). Mandal and Mukherji (2001) studied the activities of a few free radicals scavenging enzymes present in five roadside plants (growing on the edges of Delhi Road). By analyzing the activities like superoxide dismutase, ctalase, ascorbate peroxidase, glutathione reductase and phenolic peroxidase, it appears that *Amaranthus spinosus* is equipped with a very good scavenging system to combat effects of air pollution.