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ORIGINAL ARTICLES

A Review of Scientific Literature on Anti-diabetic Activity in Medicinal Plants Used by Folk Medicinal Practitioners of Two Villages in Narail and Chuadanga Districts, Bangladesh for Treatment of Diabetes

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ABSTRACT

An ethnomedicinal survey conducted amongst folk medicinal practitioners (Kavirajes) of two villages in Narail and Chuadanga districts of Bangladesh revealed the use of twenty four medicinal plant species for treatment of diabetes or alleviating diabetic symptoms in human patients. Perusal of the available scientific literature on the anti-diabetic plant species showed that out of the twenty four medicinal plants used, fifteen plant species have been reported in the scientific literature to possess considerable anti-diabetic properties directly in the form of ability to reduce blood sugar following administration, or possess properties, which can alleviate diabetic symptoms or reduce the risk factors for diabetes, including anti-oxidant and hypolipidemic properties. Overall, it can be concluded that the considerable expertise gained by the Kavirajes through long-term practice as well as passage of accumulated knowledge from generation to generation has practical validity and is not based on superstitions or myths about these plants. The close coincidences between the use of medicinal plants by the Kavirajes and their real time scientific validity studies suggest that these plants (some of which are yet to be scientifically studied) have considerable potential for discovery of novel anti-diabetic agents. Diabetes is a debilitating disease affecting millions of people worldwide including Bangladesh, and for which allopathic medicine has no known cure. As such, discovery of novel anti-diabetic agents, which even though they may not cause complete cure, but can alleviate various diabetic symptoms in a more efficient manner or reduce the risk factors leading to diabetes will be of considerable benefit to mankind. As such, these medicinal plants used by the Kavirajes need to be scientifically studied in a more rigorous manner, and efforts should be made to collect information from other Kavirajes in other villages and towns of Bangladesh on anti-diabetic plants and formulations for their uses.

Key words: Medicinal plants, folk medicine, diabetes, anti-diabetic activity, Bangladesh

Introduction

Folk medicinal practitioners are an established part of the traditional medicinal system in Bangladesh. These practitioners, usually known by the name Kaviraj, usually do not go for complicated medicinal formulations as is present in other traditional forms of medicine in Bangladesh, like the Ayurvedic or Unani system of medicine. Kavirajes, for most practical purposes, rely on simple concoctions of a single medicinal plant, and rarely uses combination of plants for treatment of any specific ailment. Even the simple concoctions, in the majority of cases, consist of extract of juice from macerated plant part(s) followed by oral or topical administration, depending upon the disease. It is really surprising to notice that although the Kavirajes do not use, or are even aware of modern diagnostic procedures, they treat complicated diseases like diabetes,

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rheumatoid arthritis, or even cancer, which they diagnose only through a thorough physical examination of the patient, measuring the pulse, and noticing the frequency, quantity and color of excretory products like stool, urine, and sometimes sweat.

Because of the advances in global civilization, the knowledge of the Kavirajes, and indeed Kaviarjes as a profession is on the decline in Bangladesh, because the young generation is seeking better and less rigorous ways of income. On the other hand, Kavirajes have been practicing for centuries, and since their knowledge is passed on from generation to generation, over the years they have attained considerable knowledge on medicinal plants and their uses. From the fact that their profession and knowledge is based at least to a certain extent on the satisfaction of the patients, it can be inferred that the medicinal plant knowledge of the Kavirajes have a certain degree of efficacy for the diseases that they treat, for their patients visit them year after year. For this reason, we have been conducting ethnomedicinal surveys among the Kavirajes of various villages in various regions of Bangladesh for the last few years. Besides Kavirajes (who belong to the mainstream population), we had been also conducting ethnomedicinal surveys among the tribal medicinal practitioners, who also use medicinal plants in their treatments, and can be considered as Kaviarjes, even though each tribe may have their own names in their own languages for such practitioners. Several accounts of these surveys among the Kavirajes and tribal medicinal practitioners have been reported (Hossan *et al*., 2010; Mollik *et al*., 2010; Nawaz *et al*., 2009; Rahmatullah *et al*., 2009a-c; Rahmatullah *et al*., 2010a-d).

Diabetes is a debilitating disease suffered by millions of people throughout the world and for which modern allopathic medicine has no known cure. Although the primary symptoms of diabetes are high levels of blood sugar and passage of sugar through urine, the disease progressively can lead to diabetic retinopathy, nephropathy, and neuropathy, besides increasing the risks for hypertension, cardiovascular disorders, and other diseases. In modern times, incidences of this disease is on the rise globally because of a more sugar-rich and fat-rich diet, as well as adoption of a more sedentary lifestyle, particularly in the cities. The prevalence of type 2 diabetes was found to be 8.5% in a randomly selected subject group of 975 people of both sexes in an urbanizing rural community of Bangladesh (Rahman *et al*., 2007). A substantial number of the rural population of Bangladesh rely on Kavirajes for treatment of diabetes, either because of inaccessibility to modern clinics and doctors or non-affordability in the purchase of high-priced allopathic anti-diabetic drugs. Since patient satisfaction in the treatment of diabetes is often reported for treatment by the Kavirajes, the objective of the present study was (a) to conduct an ethnomedicinal survey among the Kavirajes of two adjoining villages of Narail and Chuadanga districts in Bangladesh to document their use of anti-diabetic medicinal plants, and (b) to review the potency of the medicinal plants used by the Kavirajes against reported anti-diabetic activities on these plants in the scientific literature. The first objective has been reported in an accompanying paper, while this paper will deal on a review of the scientific literature on the anti-diabetic medicinal plants used by the Kavirajes and determine the validation of these plants' folk medicinal use.

Materials and Methods

The collection of data through interviews of Kavirajes was conducted with the help of a semi-structured questionnaire and the guided field-walk method of Martin (1995) and Maundu (1995). Briefly, in this method, the Kavirajes took the interviewers on field-walks to areas from where they usually collected their medicinal plants, pointed out the plants and described their uses. Plant specimens were collected and dried on the spot. Plant identifications were done by Mr. Manjur-ul-Kadir Mia, ex-Curator and Principal Scientific Officer of the Bangladesh National Herbarium.

A search of the relevant scientific literature was made through perusal of scientific journals and conducting searches through various scientific databases. All plants were screened for reported pharmacological activities, which could prove relevant to their folk medicinal use by the Kavirajes.

Results and Discussion

A total of 24 medicinal plant species distributed into 20 families were observed to be used by the Kavirajes of the area surveyed for treatment of diabetes. It was observed that the plant parts used for treatment included leaves, stems, barks, fruits, seeds, and tubers as well as whole plants. Particularly interesting was the use of cluster of flowers as well as the inner portion of trunk of *Musa sapientum*. Notably, both plant parts were advised by the Kavirajes to be taken in the cooked form. The information is shown in Table 1.

A perusal of the reported anti-diabetic and relevant activities of the anti-diabetic plants used by the Kavirajes showed that 15 out of the 24 plants used had reported anti-diabetic activities. The results are shown in Table 2. Besides anti-diabetic activity, which was directly related to lowering of blood sugar, the plants

Table 1: Antidiabetic plants used by Kavirajes of two randomly surveyed villages of Narail and Chuadanga districts, Bangladesh.

Serial Number	Scientific Name	Family Name	Local Name	Utilize Part
1	*Mangifera indica* L.	Anacardiaceae	Aam	Bark
2	*Cuminum cyminum* L.	Apiaceae	Jeera	Seed
3	*Amorphophallus campanulatus* Blume ex Decne	Araceae	Ol	Tuber
4	*Mikania cordata* (Burm.f.) B. L. Robinson	Asteraceae	Jarmany lota	Top of young stem
5	*Terminalia belerica* (Gaertn.) Roxb.	Combretaceae	Bohera	Fruit
6	*Terminalia chebula* Retz.	Combretaceae	Horitoki	Fruit
7	*Coccinia grandis* (L.) J. Voigt	Cucurbitaceae	Telakochu	Top of young stem
8	*Momordica charantia* L.	Cucurbitaceae	Korola	Fruit
9	*Emblica officinalis* Gaertn.	Euphorbiaceae	Amloki	Fruit
10	*Tamarindus indica* L.	Fabaceae	Tetul	Seed
11	*Flacourtia indica* (Burm.f.) Merr.	Flacourtiaceae	Buj, Bouchi fol	Leaf, fruit
12	*Swertia chirata* (Roxb. ex Fleming) H. Karst.	Gentianaceae	Chirota	Whole plant
13	*Azadirachta indica* A. Juss.	Meliaceae	Neem	Bark
14	*Tinospora cordifolia* (Willd.) Hook.f. & Thoms.	Menispermaceae	Guloncho	Top portion of stem
15	*Ficus hispida* L.f.	Moraceae	Job dumur	Fruit
16	*Musa sapientum* L.	Musaceae	Kola	Cluster of flowers (locally known as mocha), inner portion of trunk (locally known as thore)
17	*Psidium guajava* L.	Myrtaceae	Peyara	Bark
18	*Syzygium cumini* (L.) Skeels	Myrtaceae	Jaam	Bark, seed
19	*Piper cubeba* L.f.	Piperaceae	Kabab chini	Fruit
20	*Piper longum* L.	Piperaceae	Pipul	Fruit
21	*Aegle marmelos* (L.) Corr.	Rutaceae	Bel	Fruit
22	*Solanum torvum* Swartz	Solanaceae	Tit baegun	Fruit
23	*Centella asiatica* (L.) Urb.	Umbelliferae	Thankuni	Leaf
24	*Amomum aromaticum* Roxb.	Zingiberaceae	Elach	Fruit

Table 2: Scientific literature on anti-diabetic activity of medicinal plants reported in Table 1.

Scientific Name	Reported relevant anti-diabetic activities with references
Mangifera indica L.	a-Amylase inhibitory activity reportedly present (Zinjarde *et al*., 2011); a chemical constituent obtained from the plant, mangiferin reportedly prevented nephropathy progression in streptozotocin (STZ)-induced diabetic rats (Li *et al*., 2010); inhibitory effect of mangiferin on hyperglycemia and atherogenicity in STZ diabetic rats (Muruganandan *et al*., 2005); reported amelioration of atherogenic diet induced dyslipidemia, hypothyroidism and hyperglycemia by peel extracts of fruits (Parmar and Kar, 2008); hypoglycemic effect reported for stem-bark aqueous extract (Ojewole, 2005); anti-diabetic action and anti-hyperglycemic effect of the plant reported in mice and rat (Aderibigbe *et al*., 2001; 1999).
Cuminum cyminum L.	Anti-hyperglycemic activity and inhibition of advanced glycation end product formation reported in STZ-induced diabetic rats (Jagtap and Patil, 2010); cuminaldehyde – an aldose reductase and a-glucosidase inhibitor reportedly derived from seeds (Lee, 2005); hypoglycemic activity reported of flavonoid fraction obtained from seeds of a related species, *Cuminum nigrum* (Ahmad *et al*., 2000); reported hypoglycemic activity of seeds from a related species, *Cuminum nigrum* in normal and alloxan diabetic rabbits (Akhtar and Ali, 1985).
Terminalia belerica (Gaertn.) Roxb.	Anti-diabetic and anti-oxidant activity reported for the plant (Sabu and Kuttan, 2009); positive relationship between antioxidant property of the plant and reported anti-diabetic activity (Sabu and Kuttan, 2002).
Terminalia chebula Retz.	Reported inhibitory effect of plant extract on glycation and endothelial cell adhesion indicating a beneficial role of the extract in diabetes (Lee *et al*., 2011); a-amylase activity reported in plant extract, indicating a beneficial role in diabetes (Zinjarde *et al*., 2011); beneficial effects of fruit extract on metabolic components of metabolic syndrome (insulin resistance or glucose intolerance where the body can't properly use insulin or blood sugar) in rat model (Singh *et al*., 2010); reported beneficial effects of long-term administration of plant extract on hyperglycemia and associated hyperlipidemia, tissue glycogen content and *in vitro* release of insulin in STZ-induced diabetic rats (Murali *et al*., 2007); anti-diabetic and renal protective effects of chloroform extract of seeds in STZ-induced diabetic rats (Rao and Nammi, 2006).
Momordica charantia L.	Observed anti-hyperglycemic and anti-oxidative effect of aqueous extract of fruit pulp in alloxan-induced diabetic rats (Tripathi and Chandra, 2010); reported amelioration of pancreatic histopathological changes associated with STZ-induced diabetes in neonatal rats by plant extract (Abdollahi *et al*., 2011); demonstration of anti-oxidant and anti-hyperglycemic properties for cardiac tissue during diabetes mellitus by plant extract (Tripathi and Chandra, 2009); anti-diabetic effects reported for fruit extract in insulin-resistant db/db mice (Klomann *et al*., 2010); maintenance of normal glucose levels and lipid profiles and prevention of oxidative stress in diabetic rats subjected to chronic sucrose load (Chaturvedi and George, 2010); hypoglycemic and anti-hyperglycemic activity reported for fruits (Yadav *et al*., 2010); anti-hyperglycemic, anti-hyperlipidemic and anti-oxidant effect reported for Dihar (a polyherbal Ayurvedic formulation containing extract of the plant) in STZ-induced diabetic rats (Patel *et al*., 2009); beneficial effects reported for wound healing by extract of fruit in non-diabetic as well as STZ-induced diabetic rats (Teoh *et al*., 2009); diabetes ameliorative effects as demonstrated by effect on insulin resistance and skeletal muscle GLUT4 protein in fructose-fed rats (Shih *et al*., 2009); hypoglycemic activity reported for saponin fraction extracted from the plant (Han *et al*., 2008); beneficial

Table 2: Continue

	effect demonstrated on pancreatic islets of alloxan diabetic albino rats by alcoholic extract of whole fruit powder (Singh *et al*., 2008); reported decrease in insulin resistance and visceral obesity in mice on high fat diet by plant extract (Shih *et al*., 2008); reported anti-diabetic activities of triterpenoids isolated from fruits mediated through activation of AMPK pathway (Tan *et al*., 2008); regeneration of b-cells in islets of Langerhans of pancreas of alloxan diabetic rats by acetone extract of fruits (Singh and Gupta, 2007a); suppression of postprandial hyperglycemia in rats by extract of plant parts (Uebanso *et al*., 2007); reported improvement by fruit extract of insulin sensitivity by increasing skeletal muscle insulin-stimulated IRS-1 tyrosine phosphorylation in high-fat-fed rats (Sridhar *et al*., 2008); anti-diabetic and anti-lipidemic properties reported of standardized fruit extract (Fernandes *et al*., 2007); reported reparative effects by plant part extract on HIT-T15 pancreatic b-cells (Xiang *et al*., 2007); increased glucose uptake and adiponectin (a protein hormone exclusively secreted from adipocytes into bloodstream that modulates a number of metabolic processes, including glucose regulation and fatty acid catabolism) secretion in 3T3-L1 adipose cells by aqueous extract (Roffey *et al*., 2007); inhibition of increases in blood glucose and serum neutral fat by saponin fraction obtained from the plant (Oishi *et al*., 2007); hypoglycemic and hypotensive effects reported for whole plant aqueous extract in rats (Ojewole *et al*., 2006); anti-diabetic activity reported for major constituents isolated from the plant (Harinantenaina *et al*., 2006); extraction of a slow acting protein from fruit pulp with insulin secretagogue and insulinomimetic activities (Yibchok-anun *et al*., 2006); restoration of impaired estrous cycle in alloxan-induced diabetic rats by fruit juice (Reyes *et al*., 2006); reduced adiposity, increased serum adiponectin concentration and increased lipid oxidative enzyme activities in diet-induced obese rats fed freeze-dried fruit juice, which can be beneficial for obese persons for obesity is a leading factor for diabetes (Chan *et al*., 2005); reported hypoglycemic effects of crude polysaccharides from the plant in mice (Zheng *et al*., 2005); significant hypoglycemic activity observed in STZ-induced diabetic mice following administration of Dianex, a polyherbal formulation containing aqueous extract of the plant (Mutalik *et al*., 2005); anti-oxidant properties reported for seeds in STZ-induced diabetic rats (Satishsekar and Subramanian, 2005); anti-diabetic activity reported for seeds in STZ-induced diabetic rats (Sekar *et al*., 2005); preventive effects in alterations in lipid profile and lipogenic enzymes in alloxan diabetic rats with a combination of sodium orthovanadate and fruit extract (Yadav *et al*., 2005); significant decrease in triglyceride, low density lipoprotein and a significant increase in high density lipoprotein level and oral glucose tolerance shown with methanol extract of fruit in diabetic rats (Chaturvedi *et al*., 2004); synergistic effect reported for fruit extract with both metformin and glibenclamide in patients with non-insulin dependent diabetes mellitus (NIDDM) (Tongia *et al*., 2004); stimulation of glucose and amino acid uptakes in L6 myotubes by fruit juice (Cummings *et al*., 2004); partial reversal or normalization of various parameters in STZ-induced diabetic rats by plant juice, including reductions in Na^+ and K^+-dependent absorptions of glucose by the brush border membrane vesicles of the jejunum, normalization of diabetes-induced reduction in the mean cross-sectional myelinated nerve fibers, axonal area, myelin area and maximal fiber area (Ahmed *et al*., 2004); suppression of a lowering of energy turnover inherent with aging in diabetic rats by malt vinegar of fruit (Ichikawa *et al*., 2003); suppressive activity reported for fruits along with exercise on blood glucose levels in type 2 diabetic mice (Miura *et al*., 2004); reported inhibitory action on monosaccharide uptake in rat everted gut sacs *in vitro* by aqueous extract of plant (Mahomoodally *et al*., 2004); antihyperglycemic effects reported for extracts of fresh and dried fruits in diabetic rats (Virdi *et al*., 2003); reduction of adiposity, lowering of serum insulin and normalization of glucose tolerance in rats fed a high fat diet by freeze-dried juice of fruits (Chen *et al*., 2003); reported prevention of experimental diabetic cataract by extract of the plant (Rathi *et al*., 2002); reported hypoglycemic activity of fruit in type 2 diabetic mice (Miura *et al*., 2001); partial but significant attenuation of renal hypertrophy in STZ-diabetic mice by extract of the plant (Grover *et al*., 2001); substantial prevention by plant extract of hyperglycemia and hyperinsulinemia in high fructose diet fed rats (Vikrant *et al*., 2001); hypotriglyceridemic and hypocholesterolemic effect of fruit extract in STZ-induced diabetic rats (Ahmed *et al*., 2001); aqueous extract of fruit reportedly caused reduction in STZ-induced hyperglycemia in mice, as well as STZ-induced lipid peroxidation in pancreas of mice, RIN cells and islets, and STZ-induced apoptosis in RIN cells (Sitasawad *et al*., 2000); anti-atherogenic and hypoglycemic activity observed with freeze-dried fruit powder in rats fed with cholesterol-free and cholesterol-enriched diets (Jayasooria *et al*., 2000); modulation of xenobiotic metabolism and oxidative stress in STZ-diabetic rats fed with fruit extract suggesting that the extract may play a therapeutic role in management of Type 1 diabetic patients (Raza *et al*., 2000); hypoglycemic action reported for alcohol extract of fruit pulp in STZ-diabetic rats (Sarkar *et al*., 1996); hypoglycemic effect of aqueous extract of fruits reported in normoglycemic and cyproheptadine-induced hyperglycemic mice (Cakici *et al*., 1994); hypoglycemic effects reported for fruit pulp, seed, and whole plant in normal and diabetic model rats (Ali *et al*., 1993); delayed cataract formation in diabetic Charles Foster rats reported with fruit extract (Srivastava *et al*., 1988); extra pancreatic effect in the form of increased glucose uptake by tissues without concomitant increase in tissue respiration and increased glycogen content of liver and muscle observed with oral administration of fruit juice in rats (Welihinda and Karunanayake, 1986); reported isolation of a galactose binding lectin with insulinomimetic activities from seeds (Ng *et al*., 1986); insulin releasing activity reported for the plant (Welihinda *et al*., 1982).
Emblica officinalis Gaertn.	*In vitro* antioxidant and inhibitory potential of fruits reported against LDL oxidation and key enzymes linked to type 2 diabetes (Nampoothiri *et al*., 2011); anti-hyperglycemic, anti-hyperlipidemic and anti-oxidant effects reported for a polyherbal formulation – Dihar, containing among other plant components, extract of *Emblica officinalis* plant part (Patel *et al*., 2009); delay of STZ-induced diabetic cataract in rats by extract of plant part and enriched tannoids (Suryanarayana *et al*., 2007); anti-diabetic and anti-oxidant properties reported for the plant (Sabu and Kuttan, 2002).

Table 2: Continue

Tamarindus indica L.	Aqueous extract of seeds reportedly partially restored pancreatic b cells and repaired STZ-induced damages in rats (Hamidreza *et al*., 2010); protection of testicular dysfunctions in STZ-induced diabetic rats by MTEC – a formulated drug containing aqueous-methanol extract of the plant (Mallick *et al*., 2007); attenuation of hyperglycemia and hyperlipidemia in STZ-induced diabetic rats by aqueous extract of seed (Maiti *et al*., 2005); anti-diabetic effect reported for aqueous extract of seeds in STZ-diabetic rats (Maiti *et al*., 2004).
Swertia chirata (Roxb. ex Fleming) H. Karst.	Used as an anti-diabetic plant in Ayurvedic system of traditional medicine in India and Bangladesh; bioactive constituents reportedly include the xanthone and secoiridoid glycosides consisting of mangiferin, amarogentin, amaroswerin, sweroside and swertiamarin (Suryawanshi *et al*., 2006); significant blood glucose lowering in alloxan-diabetic rats seen with vacuum dried 95% ethanolic extract of plant (Kar *et al*., 2003).
Azadirachta indica A. Juss.	Anti-hyperglycemic, anti-hyperlipidemic and anti-oxidant effects reported for a polyherbal formulation – Dihar, containing among other plant components, extract of *Azadirachta indica* plant part (Patel *et al*., 2009); chloroform extract of the plant exhibited in murine diabetes model good oral tolerance activity, inhibited intestinal glucosidase activity, showed significant increases in glucose-6-phosphate dehydrogenase activity and hepatic, skeletal muscle glycogen content after 21 days of treatment, and at the same time demonstrated a regeneration of insulin-producing cells and corresponding increase in the plasma insulin and c-peptide levels suggesting that the plant can be a good anti-diabetic agent (Bhat *et al*., 2009); the plant has been described as a good source of amylase inhibitors (Bhat *et al*., 2008); hypoglycemic effect observed with seeds in type 2 (NIDDM) diabetes mellitus (Waheed *et al*., 2006); Dianex, a polyherbal formulation containing aqueous extract of the plant along with other components has been reported to have hypoglycemic effects in STZ-diabetic mice; additionally, the elevated levels of triglyceride, cholesterol, ALT, AST, urea and creatinine in diabetic mice were significantly reduced following administration of Dianex (Mutalik *et al*., 2005); reported protective role of extract of seeds in STZ-diabetic rats (Gupta *et al*., 2004); significant blood glucose lowering in alloxan-diabetic rats seen with vacuum dried 95% ethanolic extract of plant (Kar *et al*., 2003); reported hypoglycemic activity of plant in both normal and alloxan diabetic rabbits (Khosla *et al*., 2000).
Tinospora cordifolia (Willd.) Hook.f. & Thoms.	Beneficial effects reported for the plant against high fructose diet induced in carbohydrate and lipid metabolism abnormalities (hyperglycemia, hyperinsulinemia, hypertriglyceridemia, insulin resistance, and elevated levels of hepatic total lipids, cholesterol, triglycerides, and free fatty acids) in Wistar rats (Reddy *et al*., 2009); Anti-hyperglycemic, anti-hyperlipidemic and anti-oxidant effects reported for a polyherbal formulation – Dihar, containing among other plant components, extract of *Tinospora cordifolia* (Patel *et al*., 2009); reported hypoglycemic activity of an anti-oxidant compound saponarin, characterized as a-glucosidase inhibitor present in the plant (Sengupta *et al*., 2009); anti-hyperglycemic effect reported for Ilogen-Excel, an Ayurvedic polyherbal formulation containing the plant among other constituents; the preparation when administered to STZ-diabetic rats caused reduction in blood glucose, glycosylated hemoglobin, plasma thiobarbituric acid reactive substances and hydroperoxides and caused increased levels in plasma insulin, hepatic glycogen nd total hemoglobin (Umamaheswari and Mainzen Prince, 2007); reported restoration of antioxidants in alloxan-induced diabetic Wistar rats by ethanolic extract of the plant, which can be beneficial during diabetes (Prince *et al*., 2004); hypoglycemic and hypolipidemic action reported for alcohol extract of roots in diabetic rats (Stanely Mainzen Prince and Menon, 2003).
Musa sapientum L.	Anti-oxidant and anti-hyperglycemic actions reported for methanol and aqueous extracts of roots in alloxan-induced diabetic Wistar rats (Adewoye *et al*., 2009); hypoglycemic and anti-oxidant effect of ethanol extract of flowers found in alloxan diabetic rats (Dhanabal *et al*., 2005); administration of chloroform extract of flowers reportedly led to lowering of blood sugar and glycosylated hemoglobin and an increase in total hemoglobin, as well as demonstrated anti-oxidant effect in alloxan diabetic rats (Pari and Umamaheswari, 2000; Pari and Maheswari, 1999); anti-hyperglycemic effect observed following administration of plant (Alarcon-Aguilara *et al*., 1998).
Psidium guajava L.	Anti-oxidant and anti-glycative effects described for ethyl acetate fraction of leaf in STZ-diabetic rats (Soman *et al*., 2010); anti-hyperglycemic, hypolipidemic and hepatoprotective effects reported for raw fruit peel in experimental diabetes (Rai *et al*., 2010; Rai *et al*., 2009); reported potential of fruits in preventing diabetes in quid-chewing population of Papua New Guinea (Owen *et al*., 2008); anti-hyperglycemic effects observed with aqueous and ethanol extract of leaves in STZ-diabetic Sprague-Dawley rats (Shen *et al*., 2008); anti-diabetic activity reported for ethanol extract of stem bark (Mukhtar *et al*., 2006); hypoglycemic activity reported for leaf extracts (Wang *et al*., 2005); anti-diabetic effect of leaf extract in type 2 diabetic mice model (Oh *et al*., 2005);
Syzygium cumini (L.) Skeels	Anti-hyperglycemic, anti-hyperlipidemic and anti-oxidant effects reported for a polyherbal formulation, Dihar containing extract of the plant in streptozotocin diabetic rats (Patel *et al*., 2009); reported inhibition of adenosine deaminase activity and reduction of glucose levels in hyperglycemic patienys by aqueous extract of leaves (Bopp *et al*., 2009); anti-oxidant activity reported for leaf extracts (Ruan *et al*., 2008); therapeutic effect reported for ferulic acid isolated from an ethereal fraction of ethanolic extract of seeds against streptozotocin diabetic male rats (Mandal *et al*., 2008); a-glucosidase inhibitory activity reported for seed kernel *in vitro* and in Goto-Kakizaki rats (Shinde *et al*., 2008); reported decrease of blood sugar on administration of ethanolic extract of seeds in alloxan diabetic albino rats (Singh and Gupta, 2007b); anti-hyperglycemic effect reported for dried bark when administered to mice (Villaseñor and Lamadrid, 2006); high phenolic content and anti-oxidant activity observed in seeds (Bajpai *et al*., 2005); hypoglycemic effects observed with defatted seeds and water soluble fiber from seeds in alloxan diabetic rats (Pandey and Khan, 2002); reduction of tissue damage in diabetic rat brain reported for aqueous and alcoholic extract of seeds (Stanely Mainzen Prince *et al*., 2003).

Table 2: Continue

Aegle marmelos (L.) Corr.	Role of leaf extract shown in the regulation of insulin synthesis and release and normalizing diabetic related oxidative stress and neurodegeneration affecting the motor activity in streptozotocin diabetic rats (Abraham *et al*., 2010); anti-diarrheal activity reported in unripe fruit validating its traditional usage (Brijesh *et al*., 2009); high anti-oxidant activity (NO quenching potential) reported for aqueous alcoholic extract of barks (Kumari and Kakkar, 2008); and anti-dyslipidemic activity reported for an alkaloidal-amide, aegeline 2 isolated from leaves, in streptozotocin diabetic rats (Narender *et al*., 2007); anti-diabetogenic properties (lowering of blood glucose, glycosylated hemoglobin, and urea) on administration of ethanolic extract of plant to streptozotocin diabetic rats (Narendhirakannan *et al*., 2006); anti-hyperglycemic activity reported for scopoletin isolated from leaves in hyperthyroid rats (Panda and Kar, 2006); hypoglycemic and anti-hyperglycemic activity of seed extract reported in normal and diabetic rats (Kesari *et al*., 2006); *in vitro* increased glucose uptake activity reported for methanolic extract of the plant through activation of glucose transport in a PI3 kinase-dependent fashion (Anandharajan *et al*., 2006); protective effect on pancreas on administration of aqueous extract of fruit in streptozotocin diabetic rats (Kamalakkannan and Prince, 2005); hypoglycemic effect of leaf extract seen in alloxan diabetic rats (Ponnachan *et al*., 1993); improved functional state of pancreatic b-cells reported on administration of leaf extract to streptozotocin diabetic rats (Das *et al*., 1996); hypoglycemic activity demonstrated by alcoholic extract of leaf in glucose-induced hyperglycemic Charles Foster rats (Sachdewa *et al*., 2001); hypoglycemic effect of aqueous extract of fruits reported in streptozotocin diabetic rats (Kamalakkannan and Prince, 2003a); reversal of increased glucose and glycosylated hemoglobin levels in streptozotocin diabetic Wistar rats by aqueous extract of fruits (Kamalakkannan *et al*., 2003); anti-oxidative properties of fruit extract reported in streptozotocin diabetic rats (Kamalakkannan and Prince, 2003b); hypoglycemic and anti-oxidant activity reported for aqueous extract of leaves in alloxan diabetic rats (Upadhya *et al*., 2004); hypoglycemic effect reported in normal and streptozotocin diabetic mice as well as reversal of diabetic complications on administration of Dianex, a polyherbal formulation containing aqueous extract of the plant (Mutalik *et al*., 2005).
Solanum torvum Swartz	An a-glucosidase inhibitor has been isolated from the fruit, namely methyl caffeate (Takahashi *et al*., 2010); ethanolic extract of the plant reduced systolic blood pressure, vascular reactivity changes to catecholamines, and reversed the metabolic alterations induced by fructose, which can be of value to diabetic patients (Mohan *et al*., 2009).

contained other activities related to amelioration of diabetes-induced symptoms as well as lowering risk factors for diabetes to occur. For instance, mangiferin, a reported constituent of the plant *Mangifera indica*, prevented nephropathy progression in streptozotocin-induced diabetic rats (Li *et al*., 2010). This is an important effect for diabetes is considered a debilitating disease precisely for its ability to damage and reduce functions of major body organs like heart, kidneys, eyes, and the brain. The stem bark of the plant has reported hypoglycemic effect; notably the bark was used by the Kavirajes of the survey area for treatment of diabetes. Peel extracts of the fruit reportedly also caused amelioration of atherogenic diet induced dyslipidemia, hypothyroidism and hyperglycemia (Parmar and Kar, 2008). Fruit peels were not used by the Kavirajes, suggesting that the Kavirajes, at least of the area surveyed, were not aware of the anti-diabetic properties of fruit peels of the plant. The finding highlights the importance of more scientific studies on plants used by the Kavirajes, for like in this instance Kavirajes can benefit from scientific studies and start using plant parts, relevant properties of which they were not aware before.

By far the most scientifically studied plant was *Momordica charantia*. The fruits of this plant have a long history of use by both folk medicinal practitioners of Bangladesh as well as Ayurvedic medicinal practitioners for treatment of diabetes. Scientific studies have suggested that other plant parts of this plant, notably the seeds, also have anti-hyperglycemic effect. Moreover, the effects of various plant parts of this plant include anti-oxidative effect (Tripathi and Chandra, 2010), which is beneficiary for diabetic patients in reducing major organ damages. Healing of wounds is a major problem for diabetic patients; extract of fruits of this plant has been shown to promote wound healing in streptozotocin-induced diabetic rats (Teoh *et al*., 2009). Saponins (Han *et al*., 2008) and triterpenoid fractions (Tan *et al*., 2008) have been isolated from the plant with reported anti-diabetic activity. Whole fruit powder reportedly showed beneficial effects on pancreatic islets of alloxan diabetic rats (Singh *et al*., 2008), suggesting that the fruits may play a role in the generation of pancreatic islet cells, which can be damaged during diabetes leading to impaired secretion of insulin, and thus raising blood sugar levels. Fruits also showed beneficial effects in diabetic animals through prevention of diabetes-induced lipid profile and activities of lipogenic enzymes in alloxan diabetic rats (Yadav *et al*., 2005). This finding shows that the fruits can reduce the risk factors for cardiovascular disorders resulting from diabetes. Seeds of the plant have also been shown to possess anti-diabetic activity (Satishsekar and Subramanian, 2005; Sekar *et al*., 2005). The seeds were not used by the Kavirajes, but the scientific finding of seeds having anti-diabetic effects once again highlights that scientific research on the plants used by the Kavirajes and proper dissemination of this knowledge can prove useful in increasing the Kavirajes' ability for treatment of diseases.

That 15 plants out of the 24 anti-diabetic plants used by the Kavirajes showed scientific relevancy in their use strongly suggests that the accumulated knowledge of the Kavirajes gained through centuries old practice by successive generations, can indeed be beneficial to science in the quest for more efficacious drugs. The

Kavirajes did not use any modern diagnostic procedures for recognizing diabetes. Yet the information shows that not only they could recognize diabetes through their own methods, but also used plants, whose relevancies of use are continually being demonstrated by scientific methods. It should also be pointed out that the other 9 plants, which have not been reported in the scientific literature for anti-diabetic activities, are yet to be studied for their relevant pharmacological effects. Also interesting is the fact that there is a close correlation between the plant parts used by the Kavirajes for diabetes treatment and the scientific findings of relevant anti-diabetic activities in the same plant parts. It is therefore quite possible that the plants used by the Kavirajes have strong potential for discovery of efficacious drugs, which not only merely alleviates diabetes-induced symptoms, but may also prove to be cure for the disease itself.

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