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Isolation of an *N*-acetyl-D-glucosamine specific lectin from the rhizomes of *Arundo donax* with antiproliferative activity

Amandeep Kaur [a], Jatinder Singh [a,*], Sukhdev Singh Kamboj [a], A.K. Sexana [b], Renu Moti Pandita [b], M. Shamnugavel [b]

[a] *Department of Molecular Biology & Biochemistry, Guru Nanak Dev University, Amritsar 143 005, Punjab, India*
[b] *Pharmacology Division, Regional Research Laboratory, Canal Road, Talab Tillo, Jammu, J&K, India*

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Abstract

A lectin with antiproliferative activity towards human cancer cell lines and mitogenic towards human peripheral blood mononuclear cells was purified from the rhizomes of *Arundo donax* (Linn.) by affinity chromatography on *N*-acetyl-D-glucosamine linked to epoxy-activated sepharose-6B. The pure preparation apparently yielded a single band of approximately 15 kDa on SDS–PAGE, pH 8.3, under both reducing and non-reducing conditions. The molecular mass of native lectin was 32 kDa as determined by gel filtration chromatography. This showed the lectin to be a dimer, with subunits not held together by disulphide linkages. The *A. donax* lectin (ADL) agglutinated rabbit erythrocytes and the agglutination was inhibited by *N*-acetyl-D-glucosamine and its di- and trimer. The lectin was thermostable upto 55 °C and showed optimum activity in the range of pH 7.0–9.0 and comprised of 2.1% carbohydrate content.

Keywords: *N*-acetyl-D-glucosamine; Antiproliferative; *Arundo donax*; Lectin; Mitogen

1. Introduction

Lectins are the heterogeneous group of proteins of non-immune origin that bind reversibly to mono- and oligosaccharides with high specificity and are devoid of any catalytic activity (Lis and Sharon, 1998). It is their unique ability to recognize and bind to specific carbohydrates without chemically modifying them that makes lectins invaluable tools in biomedical and glycoconjugate research. Some lectins with different carbohydrate-binding specificities have been investigated for their diverse biological activities and functions, which have shown that the *N*-acetyl-D-glucosamine (Glc*N*Ac) and mannose specific lectins generally manifest potent insulin like activities (Ng et al., 1989). Recently, it has also been reported that the Glc*N*Ac specific lectins exhibit more pronounced antitumor effect on different cancer cell lines in comparison to the other carbohydrate specific lectins tested (Wang et al., 2000). Moreover, the anti-insect activity has generally been observed in the case of Glc*N*Ac and mannose specific lectins (Carlini and Geossi-de-Sa, 2002). In addition, binding and phagocytosis of microorganisms in animals has also been reported to mediate by the Glc*N*Ac and mannose specific lectins on macrophages (Blackwell et al., 1985; Kan and Bennett, 1985; Speert et al., 1988).

Some lectins are being investigated for their potential in the area of diagnosis and therapy of cancer (Mody et al., 1995). They interact with specific carbohydrate

* Corresponding author. Tel.: +91 183 2258802; fax: +91 183 258819 20.
E-mail address: jst2004@rediffmail.com (J. Singh).

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structures on the tumor cell surface to differentiate malignant and normal cells (Gabius, 1997; Ohba et al., 2002). Lectins have been reported to inhibit cell proliferation. A lectin from common edible mushroom *Agaricus bisporus* has been shown to exhibit a reversible antiproliferative effect in a wide range of epithelial cells and against colonic cancer cell lines (Yu et al., 1993; Parslew et al., 1999). Recently, some mushroom lectins such as *Polyporus adusta* and *Ganoderma capense* have also been reported to be endowed with antiproliferative activity towards tumor cell lines (Wang et al., 2003; Ngai and Ng, 2004).

Keeping in view the importance of lectins, much research has been focused on the search for new lectin rich sources, their simple and inexpensive isolation procedures and to evaluate their biochemical properties, physiological functions and biological activities. Recently, we have reported the isolation of a lectin from a wild cobra lily, *Arisaema flavum* with potent antiproliferative and mitogenic activity against murine cell lines (Singh et al., 2004). As a part of ongoing investigations on the search for more lectins, we report herein, the purification, partial physicochemical and biological characterization of a new Glc*N*Ac-specific lectin from *Arundo donax* Linn. (Giant reed), which is a member of Poaceae (Gramineae) as a prerequisite for further study with respect to its physiological role, including in vivo antiproliferative activity and anti-insect activity in view of the available reports, which have shown that the anti-insect activity in Gramineae has generally been exhibited by the Glc*N*Ac specific lectins (Carlini and Geossi-de-Sa, 2002). The Gramineae lectins isolated so far are either from the embryonal axes or from leaves, however, to the best of our knowledge, the present edition is the first case wherein a lectin has been isolated from the rhizomes.

2. Materials and methods

2.1. Source of materials

Underground rhizomes of *A. donax* (Linn.) were collected from shrubs growing in Balachur, Ropar, India during September–October. The plant was identified by Herbarium in the Department of Botanical and Environmental Sciences, Guru Nanak Dev University, Amritsar (Acc. no. 76). Carbohydrates, standard molecular weight markers for SDS–PAGE, Bovine serum albumin and Freund's complete adjuvant and agar were procured from Sigma, Biochemical and Reagents for Life Science Research. Ampholine in pH range 3.5–10 was procured from Amersham Pharmacia. Microtitre plates (Nunc, Denmark). Others reagents used were of reagent grade or higher.

2.2. Lectin isolation

The rhizomes were washed, cut into small pieces and soaked overnight in 0.01 M, Phosphate Buffered Saline (PBS), pH 7.2 (1:5 w/v) at 4 °C. The ground mixture was filtered through several layers of surgical gauze. The filtrate was centrifuged at 20,000*g* for 20 min at 4 °C. The supernatant was subjected to stepwise ammonium sulphate precipitation at various saturations, i.e., 0–20%, 20–40%, 40–60% and 60–80% at 4 °C. The precipitates, thus, obtained after centrifugation at 20,000*g* for 10 min were dissolved in the minimum volume of PBS and dialyzed extensively against the same buffer. The fraction having maximum specific activity was utilized for affinity purification using Glc*N*Ac linked to epoxy-activated sepharose-6B. The bound lectin was desorbed by 0.1 M Glc*N*Ac in PBS. The active fractions were dialyzed against PBS, pH 7.2 at 4 °C in order to remove Glc*N*Ac.

2.3. Hemagglutination and hapten inhibition assays

Twofold serially diluted lectin was incubated in the wells of a microtiter plate at 37 °C for 30 min with an equal volume of 2% RBC's suspension (3.5×10^8 cells/ml) from 8 sources viz human ABO blood groups, rabbit, guinea pig, sheep and goat. The reciprocal of the highest dilution of the lectin showing detectable agglutination was taken as titre of the lectin. Various carbohydrates were tested for their ability to inhibit agglutination of rabbit erythrocytes. Simple sugars and their derivatives were tested at a concentration of 100 mM, while polysaccharides and glycoproteins were tested at 4 mg/ml. Each sugar was serially diluted and mixed with the same volume (30 μl) of the lectin at twice the lowest concentration causing agglutination of rabbit erythrocytes. After incubation at 37 °C for 1 h, twice the volume of 2% erythrocyte suspension (60 μl) was added and examined after 30 min. The inhibitory activity was determined as the concentration of the hapten required for the complete inhibition of the hemagglutination.

2.4. Electrophoretic analysis and M_r determination

Electrophoresis of the affinity purified *A. donax* lectin (ADL) was carried out using polyacrylamide gel electrophoresis (PAGE), pH 8.3, carried out using 10% (w/v) gel and 7.5% (w/v) gel at pH 4.5. The subunit molecular mass of the lectin was estimated using discontinuous SDS–PAGE, pH 8.3, in the presence as well as absence of 2-mercaptoethanol using 8% (w/v) slab gel. Native molecular mass of the lectin was determined by gel filtration chromatography on calibrated Biogel P-200 column using 0.01 M PBS, pH 7.2. Isoelectric focusing of the purified lectin was carried in 5% polyacrylamide gel using carrier ampholine in pH range 3.5–10 to check the microheterogeneity of the lectin.

2.5. Metal ion requirement

Demetallization of the purified lectin sample was carried out by dialyzing 1 mg/ml of protein against 0.1 M ethylenediamine tetraacetic acid (EDTA) for 72 h (Paulova et al., 1971). One part of the demetallized lectin was dialyzed against PBS, while the other part was remetallized using 0.1 M $CaCl_2$ and $MnCl_2$ for 48 h. Hemagglutination titres of treated and untreated samples were compared to find out the role of metal ions.

2.6. Stability towards temperature, pH and denaturants

The stability of the purified lectin towards temperature and pH was determined by incubating it at different temperatures ranging from 40 to 100 °C for 15 min and by using a range of buffers (pH 1–10), followed by the determination of hemagglutinating activity. The effect of denaturing agents was determined by incubating the lectin (30 μl) with an equal volume each of urea, thiourea and guanidine-HCl for 1 h at a concentration ranging from 0.5 to 8.0 M. The effect on hemagglutination was determined by comparing the titre with untreated lectin.

2.7. Quantitative analysis of protein and carbohydrate

Protein was quantified by the method of Lowry et al. (1951) with BSA as standard. Carbohydrate content of the affinity-purified lectin was determined by using Anthrone method (Spiro, 1966) using D-glucose as standard.

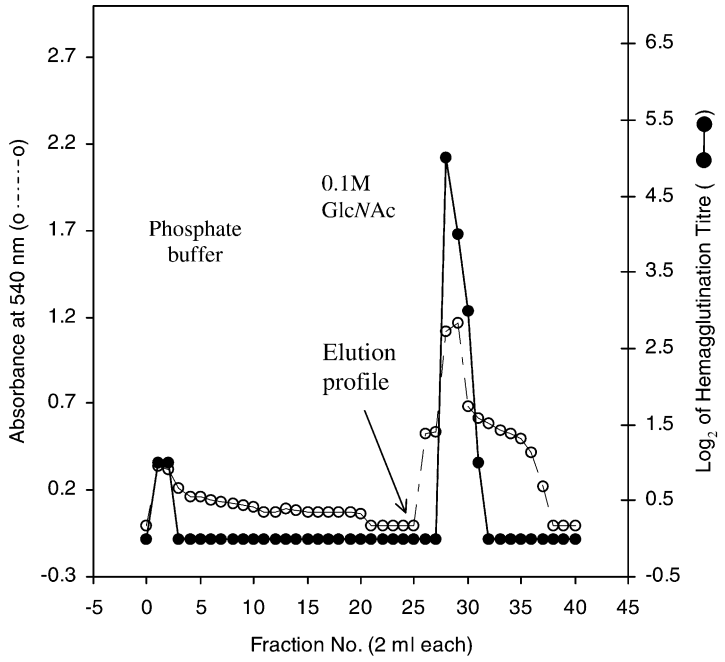

Fig. 1. Affinity chromatography of *A. donax* lectin. *N*-acetyl-D-glucosamine-linked epoxy-activated sepharose-6B column (0.8 × 3 cm) equilibrated with 0.01 M PBS, pH 7.2, was loaded with 3.5 ml of dialyzed 20–40% ammonium sulphate fraction containing 28.20 mg protein. The bound lectin was eluted with 0.1 M Glc*N*Ac. Fraction size = 2 ml; flow rate = 30 ml/h; column temperature = 20 °C. o–-–o absorbance at 540 nm (Lowry et al., 1951); (●—●) lectin activity (reciprocal of hemagglutinating titre against rabbit erythrocytes).

Table 1
Affinity purification of *A. donax* lectin

Step	Total protein (mg)	Total activity (HU)	Specific activity (HU mg^{-1})	Purification fold	Recovery (%)	MEAPC (μg/ml)
Crude extract	600	8000	13.33	1	100	75
$(NH_4)_2SO_4$ ppt. 20–40%	275	7183	26.12	1.95	89.8	38.29
Affinity purification						
Buffer profile	138.65	–	–	–	–	–
Eluted lectin	96	3866	40.27	3.02	63	25

The values given are calculated for 50 g of fresh rhizomes.
MEAPC stands for minimal erythrocytes agglutinating protein concentration.

2.8. Production of antisera and double immunodiffusion

Polyclonal antiserum against purified *A. donax* lectin (ADL) was prepared by injecting rabbit with 1 mg of lectin emulsified in Freund's complete adjuvant. Blood was collected from the ear vein, 10 days after three booster doses at one-week interval. Serum was separated by centrifugation at 10,000*g* for 10 min at 4 °C. Double immunodiffusion of ADL as well as lectins from other monocot families such as Amaryllidaceae, Araceae and Liliaceae against antisera of *A. donax* was performed in petri dishes containing 1.25% noble agar for 48 h at 37 °C in humidified chamber. The precipitin bands obtained were stained with commassie blue.

2.9. Mitogenic potential of ADL

Peripheral blood mononuclear cells (PBMC) isolated from human blood on Ficoll-Histopaque (Pharmacia, Uppsala, Sweden) by centrifugation at 400*g* for 20 min were subjected to 3,4,5-dimethylthiazol-2-yl-2,5-diphenyltetrazolium bromide (MTT) assay (Mosmann, 1983).

2.10. In vitro antiproliferative activity

The inhibitory potential of purified ADL against various human cancer cell lines such as PC-3 (Prostate), HT-29 (Colon), SiHa (Cervix), Hep-2 (Liver, hepatocarcinoma), T-47D (Cervix), SW-620 (Colon), SK-N-SH (CNS), SK-N-MC (CNS) and OVCAR-5 (Ovary) was tested by the method of Skehan et al. (1990) using ADL at concentrations ranging between 1 and 50μg/ml. Multiscan EX (Labsystems) ELISA reader was used at 540 to determine the percent growth inhibition.

3. Results and discussion

The present study describes the purification and partial characterization of a Glc*N*Ac-specific lectin from the rhizomes of *A. donax*. The lectin was purified by affinity chromatography using Glc*N*Ac linked to epoxy-activated sephrose-6B. Prior to affinity purification, the lectin was subjected to ammonium sulphate fractionation. Of the various fractions, 20–40% saturated ammonium sulphate fraction having maximum lectin activity with specific activity 26.12 was utilized for affinity purification. The absence of lectin activity in the PBS fractions indicated the complete adsorption of the lectin. The bound lectin was eluted as a single peak specifically with 0.1 M Glc*N*Ac in PBS (Fig. 1). ADL showed a purification fold of 3.02 times compared to 1.95 times of the loaded fraction (Table 1). The low purification fold indicates the high lectin content of the total extractable proteins present in the rhizomes. Similar results have earlier been reported from other monocot lectins of Amaryllid-

Table 2
Sugar specificity of *A. donax* lectin

S.No.	Sugars/derivatives	MISC (mM)
1	*N*-acetyl-D-glucosamine	+6.25
2	*N*,*N*″-diacetylchitobiose	+3.75
3	*N*,*N*′,*N*″-triacetylchitotriose	+0.625

Other thirty-two sugars and three glycoproteins tested were non-inhibitory towards ADL and not included in this table.
MISC stands for minimal inhibitory sugar concentration.

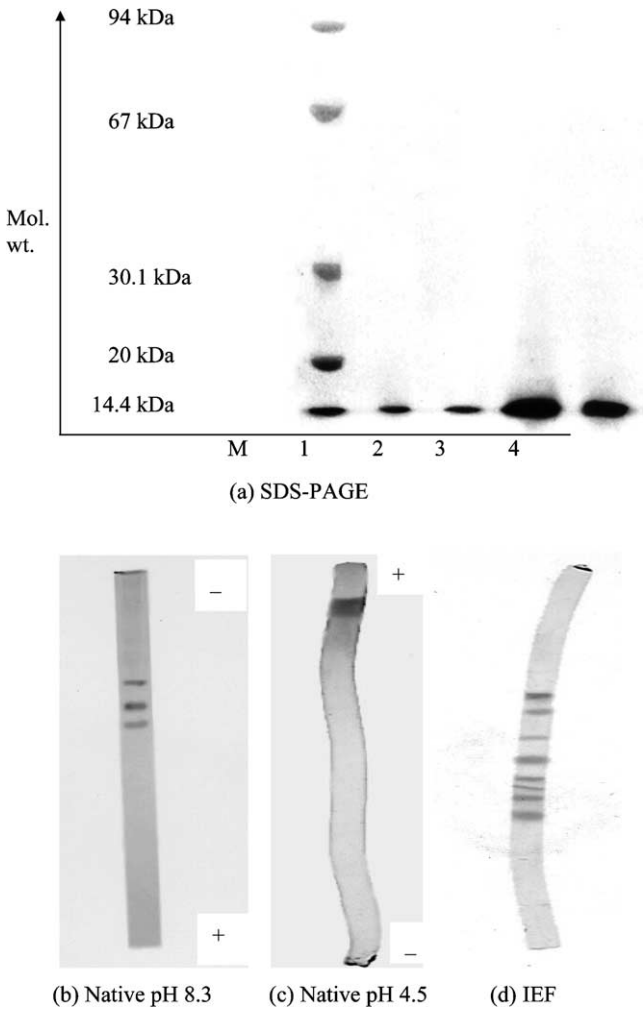

Fig. 2. Electrophoretic pattern of the purified *A. donax* lectin. The gels were stained with coomassie blue. (a) SDS–PAGE using 8% gel in the presence and absence of 2% β-mercaptoethanol. About 35 μg of the lectin was loaded, current 30 mA, voltage 100 V and run time 7 h. Lane M: Molecular weight markers, from top downwards; phosphorylase (94 kDa), bovine serum albumin (67 kDa), carbonic anhydrase (30 kDa), trypsin inhibitor (20 kDa) and α-lactalbumin (14.4 kDa), Lane 1: with mercaptoethanol, Lane 2: without mercaptoethanol, Lane 3: crude and Lane 4: 20–40% $(NH_4)_2SO_4$ fraction, respectively. (b) PAGE at pH 8.3 using 10% gel. Current 2 mA per gel, run time 7 h and protein loaded 50 μg. (c) PAGE at pH 4.5 using 7.5% gel, current 10 mA/gel, run time 9 h and protein loaded 80 μg. (d) Polyacrylamide gel isoelectric focussing of non-denatured lectin in 5% gel using carrier ampholine of pH range 3.0–10.5. Current 20 mA/gel, run time 12 h and protein loaded 20 μg.

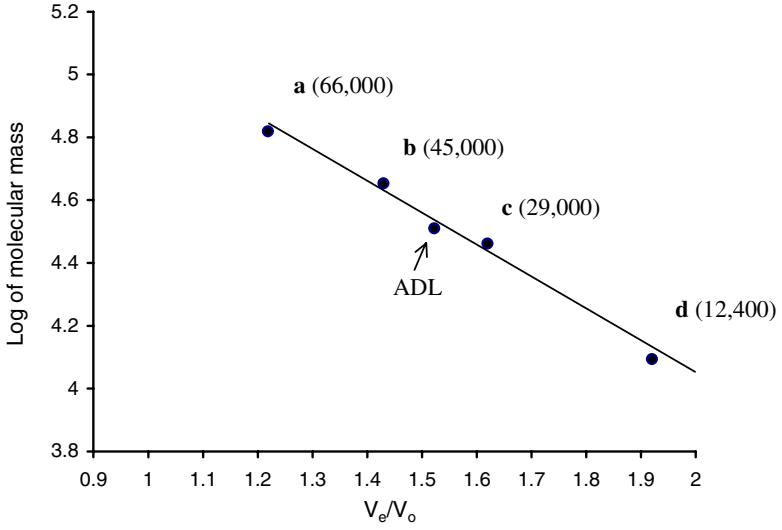

Fig. 3. Calibration curve for the estimation of molecular mass using Biogel P-200 column (67 × 0.4 cm) equilibrated with 0.01 M PBS, pH 7.2. The log of molecular mass of the standard marker proteins was plotted against their v_e/v_o. The molecular weight markers (Daltons) used were: (a) bovine serum albumin (66,000), (b) ovalbumin (45,000), (c) carbonic anhydrase (29,000) and (d) cytochrome *C* (12,400).

aceae and Araceae (Van Damme et al., 1991; Shangary et al., 1995; Van Damme et al., 1995). The data indicate that the rhizomes contain approximately 16% lectin of the total extractable proteins. The high concentration of the lectin in the storage tissue suggests its involvement in the physiological role in the plant survival (Peumans and Van Damme, 1995), which is also in consonance with the earlier findings that *A. donax* is not affected by the diseases like root rot, lesions, crown rust, stem speckle and even by the insects and pests (Bell, 1993).

In hemagglutination inhibition assays, out of thirty-five carbohydrates and three glycoproteins, the lectin activity was inhibited by Glc*N*Ac, *N*,*N*′-diacetylchitobiose and *N*,*N*′,*N*″-triacetylchitotriose at a concentration of 6.25, 3.75 and 0.625 mM, respectively (Table 2). Thus, Chitobiose was 6 times and Chitotriose was 10 times more effective inhibitor of agglutination than that of Glc*N*Ac, thereby indicating extended sugar binding site of ADL as reported for other Gramineae lectins. Apart from some lectins from Gramineae, Glc*N*Ac specific lectins have also been reported from seeds such as *Koelreuteria paniculata* (Macedo et al., 2003), in addition to a few cited lectins in a recent report on the Glc*N*Ac specific lectins from edible mushroom, *Pleurotus tuber-regium* (Wang and Ng, 2003). Most of the Gramineae lectins isolated so far are either from the embryonal axes of cereals having high specificity towards Glc*N*Ac and a few from roots and leaves of wild

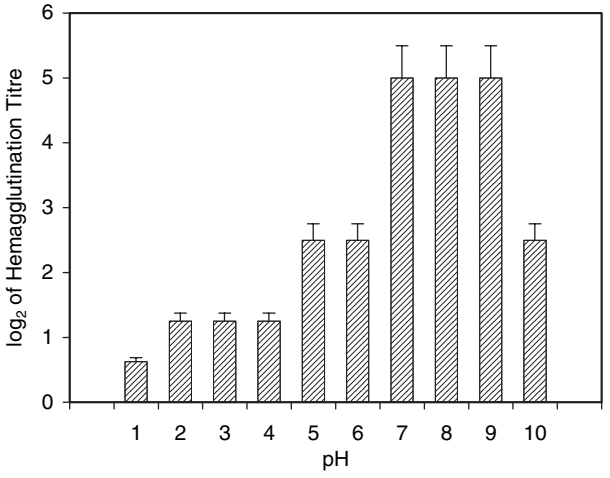

Fig. 4. Effect of pH on ADL activity. Buffer ranging from pH 1 to 10 were used. The bars represent the hemagglutination activity of the lectin. Maximum lectin activity was in the range of pH 7–9.

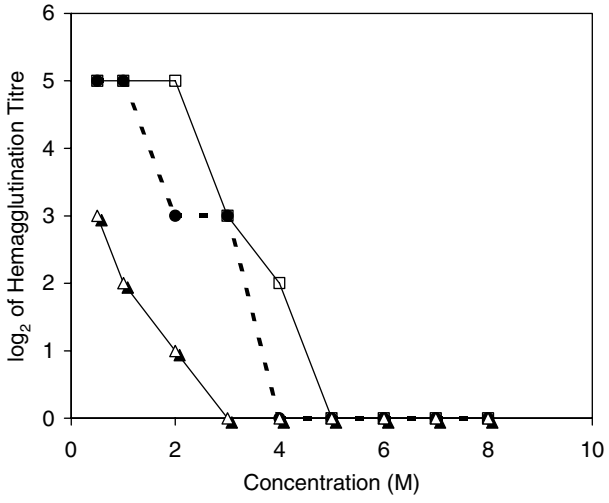

Fig. 5. Effect of denaturing agents: *A. donax* lectin was incubated for 1 h with urea, thiourea and guanidine-HCl at a concentration of (0.5–8.0 M). Hemagglutination activity was later determined. Urea and thiourea decreased its activity at 3 M while, guanidine-HCl at 0.5 M.

grasses such as *Brachypodium sylvaticum* and *Agropyrum repens*, which are reported to have *N*-acetyl-D-galactosamine (Gal*N*Ac) specificity (Peumans et al., 1982; Cammue et al., 1985). Therefore, the present edition, to the best of our knowledge, is the first case wherein a Gramineae lectin has been isolated from the rhizomes showing specificity towards Glc*N*Ac similar to that of the cereal lectins from embryonal axes, but different from those isolated from roots and leaves. The anti-insect activity, particularly in the members of Gramineae, has been reported to be related with such a sugar specificity (Carlini and Geossi-de-Sa, 2002). In general, it may also be mentioned here that most of the Glc*N*Ac specific lectins have also been reported to be antilipolytic and lipogenic (Ng et al., 1989).

ADL gave a single band in SDS–PAGE, pH 8.3, under reducing and non-reducing conditions having a subunit molecular weight of 15 kDa (Fig. 2). Similarly, it gave a single band in PAGE, pH 4.5, and a single peak in gel-filtration chromatography, thereby indicating the purity of lectin preparation. However, in PAGE 8.3, it gave three closely moving bands (Fig. 2), which may be due to the presence of charged isomers as reported in case of other monocot lectins (Singh et al., 1993). Furthermore, in IEF, this lectin gave multiple bands in pI range 4.1–5.4 due to its charge heterogeneity suggesting that it exists as a mixture of isolectins, which corroborates with earlier findings (Ooi et al., 2000). The native molecular mass of ADL was found to be 32 kDa (Fig. 3), which indicated that the lectin is a homodimer with two subunits not held together by disulphide linkages. The purified lectin was a glycoprotein like other members of Gramineae with carbohydrate content of 2.1%.

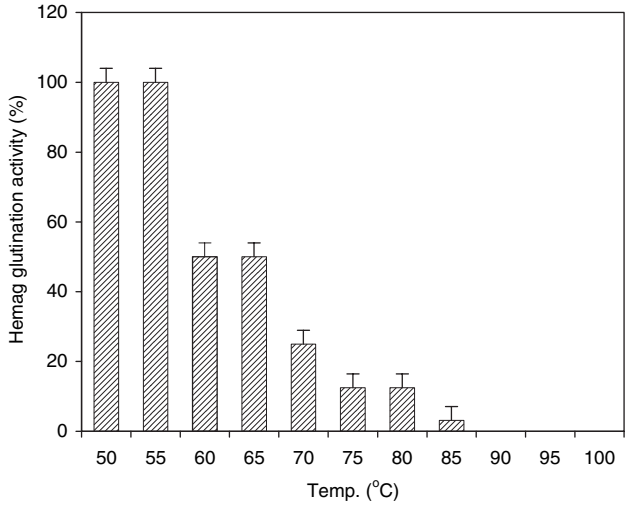

Fig. 6. Thermal stability of ADL: The lectin was incubated at elevated temperature (50–100 °C) for 15 min, cooled and tested for hemagglutination titre. The bars represent percentage hemagglutination activity of the purified lectin. Full (100%) activity correspond to a titre of 32 of the affinity purified lectin.

Arundo donax lectin showed optimum activity in a narrow pH range of 7–9 (Fig. 4). This is contrary to the other reported lectins, which are stable over a broad pH range such as lectin from seeds of *K. paniculata* stable over a pH range of 5–9, *Talisia esculenta* lectin stable at pH 3–9 and *Sphenostyles stenocarpa* lectin stable at pH 2–10 (Macedo et al., 2003; Freire et al., 2002; Machuka et al., 1999). The lectin activity was decreased at a concentration of 0.5 M in the presence of guanidine-HCl and at a concentration of 3 M in the presence of urea and 2 M with thiourea (Fig. 5). These denaturants are known to disturb the three-dimensional conformation and binding sites of lectins by affecting the hydrophobic interactions that play a crucial role. ADL is

Table 3
Biological action spectrum of *A. donax* lectin

Types of RBCs/lymphocytes	Minimal erythrocyte/lymphocyte agglutinating lectin conc. (μg/ml) (MEAPC/MLAPC)	
	Untreated	Trypsin treated
Rabbit	25	12.5
Sheep	–	–
Goat	–	63.75
Guinea pig	63.75	31.37
Human A	510	255
Human B	510	255
Human AB	127.50	63.75
Human O	–	230
Human lymphocytes	127.50	31.87

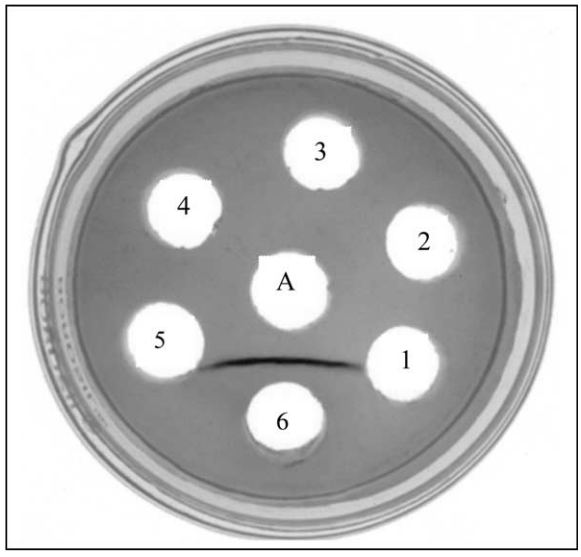

Fig. 7. Double immunodiffusion of purified ADL against rabbit antiserum: 25 μg of antisera (A). Well 1: purified lectin from *Alocasia cucullata* (Araceae); Well 2: purified lectin from *Zephyranthes candida* (Amaryllidaceae); Well 3: purified lectin from *Zephyranthes carniata* (Amaryllidaceae); Well 4: purified lectin from *Crinum latifolium* (Amaryllidaceae); Well 5: purified lectin from *Gloriosa superba* (Liliaceae); Well 6: purified ADL. The precipitin bands were stained with coomassie blue.

stable upto 55 °C for 15 min and lost its activity by 20% at 60 °C and beyond 85 °C no activity was observed (Fig. 6). ADL did not require metal ions for its hemagglutination activity. Contrary to a few earlier reported Gramineae lectins from roots and leaves, which are highly human blood group specific (Van Damme et al., 1998); ADL was found to be non-specific for erythrocytes from human A, B and AB, like the embryo lectins. However, human O and goat erythrocytes were reactive after trypsin treatment. Minimal erythrocyte agglutinating protein concentration (MEAPC) of human A, B, AB, rabbit and guinea pig erythrocytes was reduced to half when treated with trypsin (Table 3). The increased erythrocyte agglutination may be due to the increased access to the cell membrane glycoproteins containing the carbohydrate unit specific to ADL (Kassab et al., 2001). The purified ADL showed a precipitin line against its anti sera (Fig. 7) and no precipitin line with members of other monocot families such as Araceae, Amaryllidaceae and Liliaceae, which showed that lectin is serologically not related to any of these monocot species.

ADL was found to be mitogenic towards human peripheral blood mononuclear cells, which was almost double to that of the well known mitogen con A (Fig. 8). The relative mitogenic stimulation of ADL was 194. Use of mitogenic lectins as a tool to investigate the lymphocyte transformation as a model of antigen activation, initiation of cell division and growth and to know the immune status of an individual has already been known in the literature (Kilpatrick and Van Damme, 1990), which has raised the possibility to exploit the mitogenic potential of ADL through further investigations.

In vitro antiproliferative activity of ADL was evaluated against nine human cancer cell lines representing different organs and tissues. The antiproliferative effect of lectin was determined over a range of 1–50 μg/ml. ADL showed maximum effect of 62% against ovarian cell line (OVCAR-5) followed by SKN-N-MC (CNS), Hep-2 (Liver), SW-620 (Colon) and SK-N-SH (CNS) cell lines, where 59%, 53%, 51% and 45% growth inhibition was observed, respectively, at the highest concentration of 50 μg/ml. At a concentration of 30 μg/ml, the growth inhibition observed was 55% for SK-N-MC, 50% for SW-620, 48% for OVCAR-5, 45% for Hep-2; and in rest of the cell lines, it varied from 15% to 37%. However, at a lower concentration of 10 μg/ml, the growth inhibition that assume some importance was 47% and 40%, observed, respectively, in case of SK-N-MC and SW-620 cell line. The activity of the lectin was well comparable to the known anticancer drugs used as positive controls (Table 4). The lectin was found to be inactive against prostate cell line (PC-3) at all the concentrations studied. Thus, the present study showed that the lectin has in vitro cell lines specific antiproliferative potential against human cancer cell lines in a dose dependent manner (Table 4), which is in consonance with the earlier reported variation in antiproliferative potential of a variety of lectins with cancer cell lines (Wang et al., 2000).

To our knowledge, present edition is the first case wherein a lectin has been isolated from the rhizomes in Gramineae. In addition, ADL with exploitable growth inhibition potential towards human cancer cell lines and mitogenic potential towards human peripheral blood mononuclear cells along with a sugar specificity,

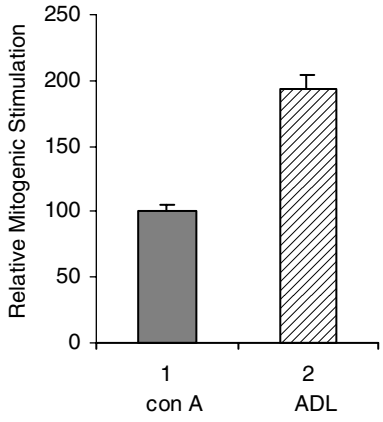

Fig. 8. Histogram showing response of human peripheral blood mononuclear cells to ADL (2) using con A (1) as positive control. Relative mitogenic stimulation of con A was taken as 100 and calculated at optimum dose, i.e., 10 μg/ml and is an average of quadruplicate cell cultures.

Table 4
In vitro antiproliferative potential of *A. donax* lectin against human cancer cell lines

Lectin/drugs	Concentration	Growth inhibition against cell lines (%)								
		T-47D	SiHa	SK-N-SH	SK-N-MC	SW-620	HT-29	Hep-2	OVCAR-5	PC-3
	1 μg/ml	6	8	9	14	12	18	23	3	0
	10 μg/ml	19	12	35	47	40	20	35	19	0
	30 μg/ml	15	24	37	55	50	21	45	48	0
	50 μg/ml	–	–	45	59	51	23	53	62	–
5-Fluorouracil	2×10^{-5} M	41	40	–	–	–	–	27	–	46
Mytomycin C	1×10^{-5} M	53	43	–	–	–	–	83	66	57
Pactitaxel	1×10^{-5} M	–	24	50	81	48	73	–	–	–

ADL, *Arundo donax* lectin.

which is reported to be involved in the diverse biological activities, has provided an interesting line of investigations with respect to lectin based diagnosis and therapy. A substantial amount of further investigations will be necessary to unravel the molecular basis for the mitogenic and antiproliferative potential of the lectin on cell differentiation and proliferation to advance understanding of lectin dependent processes.

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