Pharmaceutical binders are materials added dry or in liquid form to form granules or to promote cohesive compacts for directly compressed tablets. These include natural gums, alginic and alginates, starches, liquid glucose, cellulose derivatives and polyvinyl pyrolidone. Natural gums like acacia and tragacanth are employed in solutions ranging from 10-25% concentration alone or in combination. Together with neighboring countries, India due to its diverse agro-climatic conditions has remained the natural home of various species of natural gums since time immemorial. Gum olibanum (from *Boswellia spp*.), gum myrrh (from *Commiphora spp*.), gum karaya (from *sterculia spp*.) and gum acacia (from *A. senegal* and *A. seyal spp.*) are reported to yield gum and resin products of commercial value.

The plants selected for present studies are important agro and social forestry trees. Also, these plants were found to have gums/ mucilages of some medicinal and social uses. No work has been reported so far on the plants selected for the present study as tablet binders. Therefore, the present study was carried out to investigate the binding efficiency of local gums obtained from the plants found in Garhwal region of Himalayas in India. The binder properties of local gums were evaluated and compared with already established binders of natural origin.

The purpose of this study was to investigate the efficiency of local gums obtained from the plants found in Garhwal region of Himalayas in India as tablet binder. A study was carried to investigate the binder effect and other properties of the following plants.

- *Grewia optiva*
- *Aesculus indica*
- *Prunus persica*
- *Bombax ceiba*
- *Myrica*

The gums obtained from the above plants were used as tablet binder using two model drugs viz. Paracetamol, which is both sparingly soluble and poorly compressible drug, and Diclofenac sodium, which is a freely soluble drug.
G. optiva mucilage

In the present study, firstly an effort was made to assess the efficacy of gum mucilage of *G. optiva* as a tablet binder. The binding capability of the gum mucilage was also compared with other conventional mucilages used as tablet binder. The plant was collected in the month of February from the Himalyan region of Garhwal, Uttarakhand (India), and identified. The yield was found to be 23% w/w in form of a light brown powder. Then the mucilage was subjected for various physicochemical characterizations like viscosity, solubility, swelling index and loss on drying.

The mucilage showed superiority in its viscosity as compared to starch mucilage. Swelling characteristics studies revealed that the swelling was affected by pH of the medium and powder showed good swelling ratio in distilled water. The loss on drying was found to be less than 1.0% and was well within official limits. Then four different batches of paracetamol granules were prepared using *G. optiva* mucilage and starch as binders in concentration of 2.5%, 5%, 7.5% and 10%.

The granules were evaluated for flow properties, bulk density, tapped density, angle of repose, percent fines, Carr’s index and Hausner’s ratio. The results of the bulk density and tapped density were within the limits. The compressibility index, Hausner’s ratio and Carr’s index values obtained suggested that the granules exhibit excellent flow properties. The values of angle of repose indicated that the granules have good flow with moderate compressibility. From the study it can easily be concluded that the % fines decreases with increase in binder concentration. A low percentage of fines indicate effectiveness of binder. The uniformly mixed blend was compressed into tablets using single stroke compression machine with 9mm punch size. Compressed tablets were then evaluated for various QC parameters such as appearance, weight variation, tablet hardness, friability, disintegration time and dissolution rate.

The tablets generally had good hardness values of between 5 and 6 kg/in\(^2\). Increase in the binder concentration has also increased the hardness of tablet. From the weight variation studies, it was concluded that none of the tablets deviated from average weight beyond the prescribed limit. It was also observed that as the concentration of binder increased, the disintegration time also increased. Despite the varying physico-chemical
characteristics of the excipients, the drug release profiles of *G. optiva* were found to be similar. It was observed that all the batches passed disintegration time test according to pharmacopoeial limits. These studies showed that the gum mucilage possesses good tablet forming properties. Also, the brittle fracture index of the tablet decreased with the increase in binder concentration. The lower BFI values at higher binder concentrations are an indication that the mucilages may ameliorate capping or lamination tendency of the tablets.

From the studies performed it can be concluded that the gum mucilage isolated from *G. optiva* had comparable binding ability with starch and appears suitable for use as a pharmaceutical binder.

*Aesculus indica* mucilage

*A. indica* bark was collected in the month of April from the Himalyan region of Garhwal, Uttarakhand (India), and identified. The mucilage was isolated from the bark of and the total yield was 11% light brown powder. The dried mucilage was studied for percentage yield, chemical test, particle size, weight loss on drying, solubility, viscosity, pH, swelling index, bulk and tapped density, angle of repose, compression properties, and microbial load. The loss on drying which indicates the amount of moisture present in the material available to interact with other materials during processing was well within official limits. The result of microbial testing of the mucilage was within official limits \{less than 100 colony-forming units (cfu)/g\}. The swelling ratio of mucilage was determined in different media and ratio was found to be highest in distilled water i.e., 40. There was a significant change in swelling by the end of the study, which indicated that the mucilage had excellent swelling properties.

The granules were evaluated for flow properties, bulk density, tapped density, compressibility index, Angle of repose, Carr’s index, Hausner’s ratio. The flow properties and compressibility of the dried mucilage, including bulk and tapped density, Carr’s index, the Hausner’s ratio, and the angle of repose, were assessed. The compressibility index and angle of repose indicated that the powder is having good flow with moderate compressibility.
The 400 mg tablets, each containing 100 mg of diclofenac sodium, were prepared using dried mucilage of *A. indica* in various drug–mucilage ratios (1:0.5, 1:1, 1:1.5, and 1:2) and were coded as A₁ –A₄.

The physical tests like hardness test, friability, and weight variation were performed for all formulations. Average hardness for all formulations was found between 5 to 6 kg/cm², friability was less than 1%. From this work, it could be shown that dried mucilage possesses good tablet forming properties.

The study of dimensional changes in the tablets was carried out for 5 h in distilled water. The radial and axial swellings of the tablets were found to be increasing with increase in the proportion of the dried mucilage. The swelling of the tablet was found to be lowest for formulation A₁. As the ratio increased, the radial and axial swelling increased proportionally. The swelling of the tablet in the axial direction was found to be more as compared with the radial direction.

As regards the effect of mucilage concentration, decrease in drug release rate was observed when *A. indica* contents in the tablets were increased. This may be due to the reason that the mucilage in higher concentrations in the tablets might have produced dense matrix around the drug particles, providing more barriers for them to escape and dissolve. Further, such dense matrix, specifically when it is hydrophobic in nature, may be expected to favor less penetration of the dissolution medium in the tablet. This may also be the auxiliary reason for obtaining slow drug release profiles through *A. indica* tablets. The results obtained showed that as the proportion of mucilage increases, the overall time of release of the drug from the tablets increases.

From the study, the mucilage extracted from *A. indica* appears suitable for use as a pharmaceutical excipient in the formulation and manufacture of sustained-release tablets because of its good swelling, good flow, and suitability for direct-compression formulations. From the dissolution study, it was concluded that the dried mucilage can be used as an excipient for sustained-release, modified-release, and fast-release tablets with suitable modifications.
P. persica mucilage

P. persica was collected and identified. The mucilage was isolated from the bark and the total yield was 19% in form of a light brown powder. The four different concentrations viz. 2.5, 5.0, 7.5 and 10% of mucilage were prepared and subjected for various physicochemical characterizations like viscosity, chemical test, microbial count, solubility, swelling index and loss on drying. The mucilage showed superiority in its viscosity as compared to starch mucilage. The presence of mucilage in extracted material was confirmed using Molisch's test and by treatment with ruthenium red. Both tests confirmed the presence of mucilage. The result of microbial testing of the mucilage was within official limits {less than 100 colony-forming units (cfu)/g}. The solubility studies showed that the powder was slightly soluble in water and practically insoluble in organic solvents. The swelling ratio of the mucilage was found to be higher for water i.e., 48 and low values were recorded in 0.1NHCl and PBS (pH-7.4). Swelling characteristics studies revealed that the swelling was affected by pH of the medium and the powder showed good swelling ratio in distilled water. The loss on drying was found to be less than 1.0% and was well within official limits.

The granules were prepared using the wet granulation method. Four binders, gelatin, acacia, starch and P. persica gum were used at five concentration levels (2 - 10% w/w). Microcrystalline cellulose (5% w/w) was employed as the disintegrant. The evaluation parameters like flow rate determination, angle of repose, bulk density, tapped density, Carr’s index and Hausner’s ratio were also determined. The flow rate increases with increase in binder concentration and then decreased after an optimum value. Granules formulated with P. persica gum had the highest flow rate at 1 - 2% w/w binder concentrations. The angle of repose decreases with increase in the binder content of the granules. This may be attributed to the reduced cohesive forces of the larger granules formed at higher binder concentration. Granules produced with P. persica mucilage demonstrated the highest reduction in angle of repose. The angle of repose values were found to be less than 40°, suggesting good flow properties. Angle of repose is a measure of powder resistance to flow under gravity due to frictional forces resulting from the surface properties of the granules. The results of the bulk density and tapped density were
found to be within the limits. The compressibility index and Carr’s index values obtained suggested the powder to exhibit excellent flow and compression properties.

The compressed tablets were subject for testing of hardness, friability and uniformity of weight. No significant variation in the mean weights of diclofenac sodium tablets was observed, since all showed low coefficient of variations of below 2%. Good tablet weight uniformity is an indication of a good uniformity of tablet contents. An increase in binder concentration increases the hardness of the tablets. On the other hand, friability decreases on increasing the binder concentration. An increase in binder concentration will enhance the formation of stronger inter-particulate bonds between the granules during compression in a tablet machine. This means that the tablets would offer greater resistance to shock and abrasion since there is a stronger adhesive bonding of the granules at high binder concentrations.

In general, the tablets showed good friability profiles, since most had friability values of less than 1.0%. Moreover, the tablets made from *P. persica* mucilage had high hardness/friability ratios, since the tablets recorded the highest hardness and least friability values. The tablets formulated with *P. persica* mucilage failed the Pharmacopoeial disintegration time test. The binders follow this order of increasing tablet disintegration time: acacia < gelatin < *P. persica* mucilage.

The dissolution data of the tablets indicated that the tablets made with acacia gave the highest drug release while tablets made from *P. persica* mucilage had the lowest. As the binder concentration increases, there was a general decrease in the release rate of diclofenac sodium from the tablets. *P. persica* mucilage displayed a very remarkable delay in the release rate at higher binder concentrations.

It may be concluded that *P. persica* gum could not be suitably employed in conventional tablet formulation as a binder since it prolongs tablet disintegration time and also remarkably delays drug dissolution rate. Perhaps it may be a good candidate for evaluation as a release retardant or hydrophilic polymer in sustained release tablet formulation.
**B. ceiba mucilage**

*B. ceiba* bark was collected in the month of May from the Himalayan region of Garhwal, Uttarakhand (India), and was identified. Two different laboratory developed methods A and B were tried for extraction of gum mucilage. The yield was 7% and 19% w/w for method A and method B, respectively. The mucilage obtained by each method was a dark brown powder. The mucilage powder that was obtained by method B was evaluated further because of higher yield. The four different concentrations viz. 2.5% 5.0%, 7.5% and 10% of the mucilage were prepared and were subjected for various physicochemical characterizations like viscosity, solubility, swelling index and loss on drying. The mucilage showed comparable results as shown by standard binder (starch).

Four different batches of paracetamol granules using *B. ceiba* mucilage and starch binders in concentration of 2.5%, 5%, 7.5% and 10% were prepared by using paracetamol & other excipients. The granules were evaluated for flow properties, bulk density, tapped density, Angle of repose, Carr’s index and Hausner’s ratio. The results of the bulk density and tapped density were within the limits. The compressibility index and carr’s index values obtained suggested the powder to exhibit excellent flow properties. The values of angle of repose indicated that the powder have good flow with moderate compressibility. The compressibility index and angle of repose indicated that the powder have poor flow with moderate compressibility. The results obtained were quite promising in comparison to the established conventional binder starch.

The uniformly mixed blend was compressed into tablets using single stroke compression machine. Compressed tablets were then evaluated for various QC parameters such as appearance, weight variation, tablet hardness, friability, disintegration time and dissolution rate.

It was found that none of the tablet deviates from the average weight. The tablets generally had good hardness values of between 4.5 and 6 kg/in$^2$. Increase in the binder concentration has also increased the hardness of tablet. With increase in the concentration of the mucilage decrease in friability values was observed. The friability values were found to be within the limits. From the studies, it can easily be concluded that the % fines decreases with increase in binder concentration. A low percentage of fines indicate
effectiveness of binder. It was also observed that with increase in binder concentration, the disintegration time also increased. It was observed that all the batches passed disintegration time test according to pharmacopoeial limits. All the results obtained were quite comparable with starch binder and it was found that almost all the results showed similar release pattern as shown by the starch mucilage.

The tensile strength increases with increase in the binder concentration. The results obtained were quite promising. This increase may be attributed to the inter-connective structural differences in the polymer. Such interconnectivity properties may influence the intrinsic properties. Brittle fracture index of the tablet decreased with the increase in binder concentration. The lower BFI values at higher binder concentrations are an indication that the mucilages may improve capping or lamination tendency of the tablets.

*Myrica mucilage*

An effort was made to assess the efficacy of gum mucilage of *Myrica* as a tablet binder. The binding capability of the gum mucilage was also compared with other conventional mucilages used as tablet binder.

The bark was collected in the month of February from khirsu, Pauri Garhwal, Uttarakhand (India) and was identified. The mucilage obtained was a brown powder and yield was 12% w/w. The mucilage was subjected for various physicochemical characterizations like viscosity, chemical test, microbial load, solubility, swelling index and loss on drying. The mucilage showed superiority in its viscosity as compared to starch mucilage. The presence of mucilage in extracted material was confirmed using Molisch's test and by treatment with ruthenium red. Both tests were found positive for the presence of mucilage. The result of microbial testing of the mucilage was within official limits (less than 100 colony-forming units (cfu/g). The solubility studies showed that the powder was slightly soluble in water and practically insoluble in organic solvents. Swelling index of the mucilage was found to be 28 in water. Low values of swelling index were obtained for 0.1N HCl and PBS. Swelling characteristics studies revealed that the swelling was affected by pH of the medium and powder showed good swelling ratio in distilled water. The loss on drying was well within official limits.
Four different batches of paracetamol granules using *B. ceiba* mucilage and starch binders in concentration of 2.5%, 5%, 7.5% and 10% were prepared by using paracetamol & other excipients. The granules were evaluated for flow properties, bulk density, tapped density, Angle of repose, Carr’s index and Hausner’s ratio. The results of the bulk density and tapped density were within the limits. The Carr’s index values for M1, M2 and M3 were found to be higher and indicated the poor flow. The compressibility index and angle of repose indicated that the powder have poor flow with moderate compressibility. The uniformly mixed blend was compressed into tablets using single stroke compression machine. Compressed tablets were then evaluated for various QC parameters such as appearance, weight variation, tablet hardness, friability, disintegration time and dissolution rate. It was found that none of the tablet deviates from the average weight. The tablets generally had good hardness values of between 5.0 and 6.5 kg/in$^2$. Increase in the binder concentration has also increased the hardness of tablet. With increase in the concentration of the mucilage decrease in friability values was observed. The friability values were found to be within the limits. A low percentage of fines indicate effectiveness of binder.

The disintegration studies and dissolution studies showed that the gum mucilage possesses good tablet forming properties. Brittle fracture index of the tablet decreased with the increase in binder concentration. The lower BFI values at higher binder concentrations are an indication that the mucilages may improve capping or lamination tendency of the tablets.
Conclusions

The last two decades have witnessed a mammoth growth in the development of drug delivery systems based on excipients of natural origin. The present study was aimed at searching for new herbal excipients especially binders and/or release retardants. Mucilages obtained from five different plants of Himalayan origin viz. *G. optiva, A. indica, B. ceiba, P. persica* and *Myrica* were evaluated for their potential as binder and/or release retardant. Two model drugs were selected for the purpose because of their poor compression properties so that they require a binder to form good quality tablets. The study was carried out using well established experimental protocols. The main conclusions drawn from the study are listed below.

The plants selected for present study are important agro and social forestry trees. Also, these plants contain gums/ mucilage of medicinal and social uses. Exhaustive literature survey revealed that no work has so far been reported on these plants for their potential as tablet binder or release retardant. Moreover, the fact that these plants are widely distributed in nature, abundantly available in India they can be easily explored and tried without disturbing the environment. The mucilage was obtained from these plants using simple extraction procedures and evaluated qualitatively and quantitatively.

I. The studies with *G. optiva* indicated that the gum mucilage obtained from this plant possesses binding ability comparable to standard binding agents in vogue.

II. The mucilage extracted from *A. indica* appears suitable for use as a binder in the formulation and manufacture of tablets in low concentrations because of its good swelling, good flow, and suitability as compressible excipient. From the dissolution study, it was concluded that the dried mucilage can be used as an excipient for sustained-release or modified-release tablets with suitable modifications.

III. It can be inferred that *P. persica* gum could not be suitably employed in conventional tablet formulation as a binder since it prolonged tablet disintegration time and also remarkably delayed drug dissolution rate. Perhaps it may be a good candidate for evaluation as a binder or hydrophilic polymer in sustained release tablet formulation.
IV. It was further noted that *B. ceiba* mucilage could be used as potential binder in tablet formulation. It appears to be an effective binder and exhibits comparable properties as shown by standard binder (starch).

V. It was observed that the tablets prepared using the *Myrica* mucilage as binder are comparable with tablets prepared using starch as binder. It can therefore be concluded that the mucilage obtained from *Myrica* possesses good binding properties and is a suitable binder of natural origin.

VI. Though the extracted mucilage(s) have proven their utility as tablet excipients, there is a need to undertake further studies in respect to scale up of extraction methods and manufacturing of tablets. Also the economic aspects are needed to be assessed.