Combating opium-linked global abuses and supplementing the production of edible seed and seed oil: A novel non-narcotic var. *Sujata* of opium poppy (*Papaver somniferum* L.)

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Successful development of a non-narcotic (opiumless and alkaloid-free) var. Sujata of opium poppy for the first time in the world has heralded a new era of opium poppy cultivation which need not be licensed. This novel variety offers a cheap and permanent natural means of combating opium-linked social abuses across the world. It is also a high calorie and protein-rich (>23%) seed (food) crop. Its seeds possess higher oil content (50–>52%) with greater proportion of hypocholesterolemic unsaturated fatty acids, than the major oilseed crops, viz. rapeseed and mustard in India. Hence, the var. Sujata is a potential supplement to the production of healthful vegetable oil, referred to as 'Sonola', for a good dietary control for coronary heart disease. Besides, it forms a sound parental base for development of hyper-alkaloid true CPS chemotypes/varieties for pharmaceutical purposes.

PERHAPS no medicinal plant hitherto on record possesses a rich food value together with an excellent pharmaceutical property as does the opium poppy (*Papaver somniferum*)[1]. Moreover, its historic and contemporary importance coupled with the notoriety and mystique can be attributed to very few plants[2]. The 'sleep-inducing' property of its byproduct, i.e. opium (dried latex) obtained by lancing the ripe fruits (capsules) of plants has been known and exploited throughout the course of human history[3,4]. Even today, its pharmaceutical significance in modern medicine is unparalleled, chiefly because of the three morphinane alkaloids, namely morphine, codeine, and thebaine and the three phthalideisoquoline alkaloids, viz. papaverine, narcotine and narcine that it contains. In addition to opium, the poppy-straw (capsule hull + 1/3 peduncle) is also the site of accumulation, though in much lower concentration, of alkaloids, which can be solvent-extracted and concentrated chemically for diverse pharmaceutical uses[5]. Besides, poppy seeds (*Posta* or *Khas-Khas*) and seed oil are also the important economic byproducts of opium poppy[3,6]. The delicious protein-rich seeds are used in certain food items while the seed-oil (fatty acid – technically called lipoprotein) is a very healthful cooking medium[7,8], it contains a large proportion of unsaturated fatty acids, viz. oleic and linoleic acids (high level of HDL, i.e. high density lipoprotein – a 'good cholesterol'), which offer a very good dietary control for the coronary heart disease (CHD).

Among the opium alkaloids, morphine is a strong analgesic, while codeine is antitussive and papaverine antispasmodic. Besides being a potent pain-killer, morphine, the largest component of opium, exhibits a combination of depression and stimulation in the central nervous system (CNS) and the gut[9]. Thus, opium causes sedation and euphoria simultaneously. The user feels relieved of pain and anxiety and tends to ever remain in the heavenly bliss, which obviously leads to opium-addiction. Therefore, opium and morphine both are addictively strong narcotic products.

Owing to its intoxicating property and rendering a blissful 'kick', illicit cultivation of opium poppy and illegal use of opium have perpetuated as a social evil for centuries. With easy chemical conversion of morphine into the still stronger narcotic compound – the notorious heroin, opium-linked abuses have now assumed a menacing proportion across the world. Today, around 17 million people are reported to be opium-addicts and nearly half as much addicted to heroin throughout the world. About two million people are opium-addicts in India. The cases of seizures of opium and heroin are whoppingly increasing – from 5299 cases of heroin seizure registered in 1991 to 14,596 in 1994 and much more lately. The 'Golden Triangle' (comprising Thai-

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land, Myanmar and Laos) and 'Golden Crescent' (Iran, Afganistan and Pakistan) are the two hot-spots engaged in such nefarious activities of production of opium and heroin and drug trafficking via Balkan route (Turkey, Bulgaria and Hungary) through Pakistan and India and recently Taiwan. The trend is dangerously upbeat unless an effective control over the production of opium and morphine is exercised. A couple of years ago, Sharma[10] had raised the vital 'opium question' of how to combat the problem of opium-linked global abuses by natural means.

One approach is crop-substitution, i.e. replacement of poppy cultivation by equally remunerative crops like German chamomile (*Matricaria recutita*), isabgol (*Plantago ovata*) or *Chrysanthemum morifolium*[10]. Another is growing *Papaver bracteatum* which synthesizes neither morphine nor codeine but only thebaine, as is practiced in some Mediterranean countries[11–13]. But it is not successful in subtropical conditions in India. Still another viable approach widely in vogue under the aegis of the International Narcotic Control Board (INCB), Vienna, is shifting the emphasis from opium-collection (gum-gathering) to extraction of alkaloids from the straw. This involves growing concentrated poppy-straw (CPS) cultivars rich in straw-morphine/codeine[14]. All the poppy-growing countries (covering an area of about 300,000 ha) except India are now following this practice. Development of alkaloid-rich CPS varieties is, therefore, a common practice in the world and several CPS varieties, viz. *Cosmos* (Hungary), *Lazur* and *Modry* (Poland), etc. have been developed in various countries[15–20]. In India also, we are aware of the international state-of-the-art[21] and therefore, have developed a CPS var. *Sanchita* with >1.0% morphine in straw (better than 0.7% in Tasmania, Australia). Alternatively, Liersch and Krzymanski[22] suggested breeding CPS varieties with negligible or no amount of narcotic alkaloids (morphine, codeine) in their straw. Therefore, screening of some CPS varieties and lines e.g. Swedish var. *Soma*, Polish var. *Przenko* and German var. *Riesenmohn* for detecting low morphine (≈ 0.01%) plants was carried out by Nothnagel *et al.*[16] in Germany. In India also, an accession with 0.05% straw-morphine was identified earlier[23]. However, such efforts are not permanent solutions of the problem of opium abuse because such CPS varieties are not free from opium/latex, hence can be incised/lanced to collect opium by unscrupulous growers. Then, could it be possible to inactivate or arrest the function of the genes/enzymes controlling the biosynthesis of opium and opium-alkaloids in the opium poppy plant? More than a decade ago, this was articulated by Sharma and Singh[24] as one of the future prospects in opium poppy.

A cheap and permanent natural solution

Physiologically/metabolically disturbed plants of opium poppy bearing no opium do occur in nature. Long ago, such plants, referred to as *Bunjha*, were reported to occur in Indian land races[25]. At the Central Institute of Medicinal and Aromatic Plants (CIMAP) also, as early as in 1981–82, we collected 35 *Bunjha* plants in our breeder's nursery of germplasm collections. But all their progenies reverted to normal[26]. During 1994, we commenced a systematic and concerted programme for conversion of the narcotic opium poppy into a non-narcotic crop by inactivating the opium gene through mutation breeding. We have now developed and stabilized (>99% homozygosity) an opiumless and alkaloid-free var. *Sujata* of opium poppy[1]. It does not exude latex (opium) on 'ray-plucking' or lancing (Figure 1). The capsule hulls (straw) have no opium alkaloid either.

This var. *Sujata* might offer a cheap and permanent natural solution to the problem of opium-linked social abuses across the world. It gives a perfect non-narcotic crop – no opium and no opium-alkaloids, hence no abuse. Thus the social ills related with opium can be put to an end. Indeed, the var. *Sujata* might prove to be the harbinger of global peace by eradicating opium abuses during the 21st century.

The var. *Sujata* may also be marshalled to derive other multiple uses as described here.

Var. *Sujata*: A potential seed (food) crop

Of nearly 300,000 plant species occurring on earth, only 40 species provide most of the calories and proteins to human beings, with 50% being contributed by nine species of cereals[27]. There has hardly been any addition to this list for more than a century[28], though man has always been looking for a new plant species to be used as a food crop. Opium poppy seeds have undoubtedly been used as food since prehistoric times. Ancient Sumerians (now in Iraq) and Southern Europeans used its seed as food as early as 4000 BC (refs 4, 6). Even in India, poppy seeds have been used for culinary purposes since 16th century BC (ref. 3). But it was not included in the above list because as a narcotic crop its cultivation has never been safe and unrestricted, like other food crops such as cereals or oilseed crops. This was obviously a great barrier to its being exploited as a food crop with high production of seeds.

Var. *Sujata* has successfully broken this barrier and made a *breakthrough* by converting the 'opium poppy' into 'seed poppy'. Being non-narcotic (no risk of opium or opium-alkaloids), it can be grown as a seed crop safely and extensively for augmenting the world food production in general and of India in particular.

The comparison of seed producing ability and seed quality (protein content) of var. *Sujata* against the best check var. *Sanchita* revealed that it was the moderate seed yielder at par with var. *Sanchita* (Table 1). But with 23.9% seed protein, it was better than the check

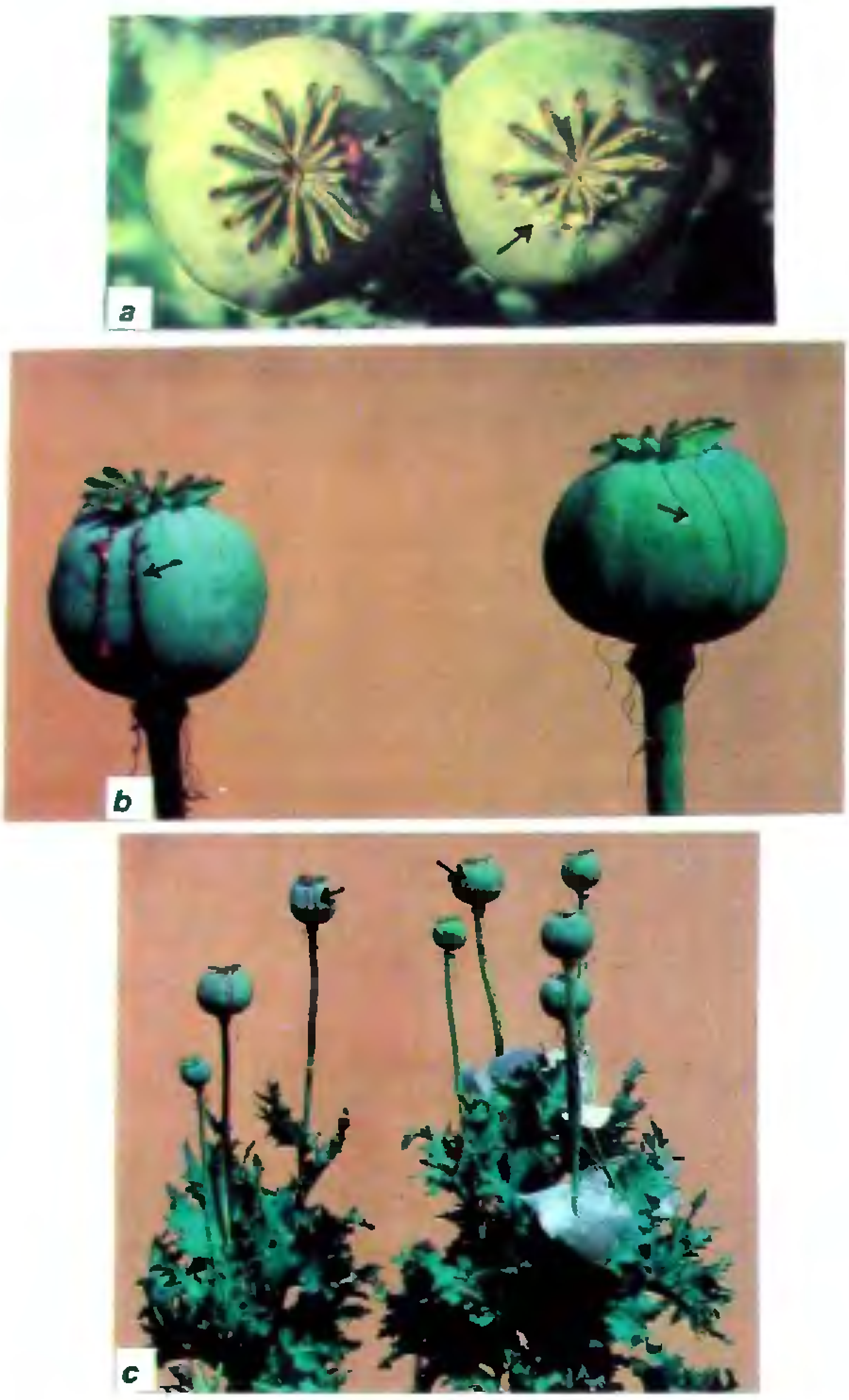

Figure 1. Latex (opium) oozing out in capsules of a normal plant (left) and no latex flowing in var. *Sujata* (right) of opium poppy. ***a***, 'Ray-pluck' test; ***b***, Lancing test; ***c***, Normal and Sujata plants after lancing.

var. *Sanchita* which manifested 20.8% protein. Indian opium poppy has been found to have 22.3 to 24.4% seed protein[7], while European poppies have 25–35% protein[8]. However, the white seeds of var. *Sujata* score over the black seeds of European poppy varieties with respect to preference in confectionery, culinary and bakery industries, especially in India. Thus, var. *Sujata* of opium poppy is a potential food crop with high nutritive value.

Var. *Sujata*: A viable supplement to edible oilseed crops

There has undoubtedly been a significant improvement in oilseed production in the last decade in India[29,30]. But the total production of oilseeds remained inadequate to meet the national demand for edible oils: the deficit was made up by importing 0.8 m tonnes of vegetable oil during 1994–95 and 0.15 m tonnes in 1995–96 (ref. 31). Export of vegetable oil is a distant dream. Among all the nine major oilseed crops, more than 60% oilseed production is accounted for by groundnut and rapeseed and mustard[32]. While the former is grown as both *kharif* (monsoon) and *rabi* (winter) crops, the latter is raised as a *rabi* crop which can be supplemented with the opium poppy var. *Sujata* during the same season for oilseed production. Var. *Sujata* giving 10–12 q/ha seed yield is nearly at par with mustard crops giving 8–15 q seeds per hectare[33]. But it is superior in seed oil content which ranges from 50.5 to 52.6% in comparison to maximum 48% oil in rapeseed and mustard (Table 2). In *Brassica juncea* (mustard), which now occupies a much greater area than *B. campestris* (rapeseeds), the oil content is even less – around 43% only, though it gives better seed yield per unit area. Therefore, the total production of seed oil per unit area of var. *Sujata* would axiomatically be equal to or more than rapeseed and mustard in India.

Table 1. Seed yield and seed protein of var. *Sujata* compared to sister strains and standard check var. *Sanchita* and parent *Sampada* of opium poppy

Genotypes (Strains/var.)	Seed yield* (kg/plot)	Seed protein (%)
LL-34 (var. *Sujata*)	0.81	23.9
LL-14	0.60	23.9
LL-33	0.49	21.6
PL-47	0.65	22.3
PL-81	0.75	21.6
Sanchita	0.92	20.8
Sampada	0.83	22.3

*Plot size: 5 rows of 3 m each, 40 cm apart.

Table 2. Oil content in seeds of var. *Sujata* and sister strains/var. of opium poppy compared to that in rapeseed and mustard

Crop/genotype	Range of oil content (%)
Opium poppy (*Papaver somniferum*)	
LL-34 (var. *Sujata*)	50.6–52.6
LL-14	50.6–51.9
LL-33	49.3–53.4
PL-47	49.3–52.6
PL-81	55.2
Sanchita	51.8–52.7
Sampada	45.8–52.6
Mustard (*Brassica juncea*)*	35.5–42.9
Var. *Varuna*⁺	37.3–40.7
Var. *Kranti*⁺	35.0–39.8
Yellow *sarson* (*B. campestris*)*	41.0–48.0
Brown *sarson* (*B. campestris*)*	40.5–45.9
Toria (*B. campestris*)*	40.5–43.7

*Source: NRC[33] (1996), ⁺NRC[33] (1998, PB55–56).

Table 3. Unsaturated fatty acid composition of the oil of var. *Sujata* and sister strains of opium poppy versus mustard

Crop/genotype	Unsatured fatty acids (%) Oleic (18:1)	Linoleic (18:2)	Linolenic (18:3)	Total
Opium poppy (*Papaver somniferum*)				
LL-34 (var. *Sujata*)	19	56	3	78.0
LL-14	20	0.5	1	21.5
LL-33	18	65	–	83.0
PL-47	28	12	5	45.0
Sanchita	16	65	–	81.0
Sampada	19	6	–	25.0
Mustard (*Brassica juncea*)*	8.9–38.1	14.6–36.1	10.5–22.3	–
Var. *Varuna*⁺	12.2	17.5	17.3	47.0
Var. *Kranti*⁺	9.2	16.2	19.8	45.2

*Source: NRC[33] (range, analysed at Kanpur, 1996), ⁺NRC[33] (1998, B6)

In addition, the oils of rapeseed and mustard have high proportion of long chain fatty acids which are less digestible in test animals[34]. High concentration of erucic acid (5–45%) and low concentration of unsaturated fatty acids, viz. oleic acid (8.9–38.1%), linoleic acid (14.6–36.1%) and linolenic acid (10.5–22.3%) in 800 samples of mustard oils analysed at Kanpur[33] are also their negative scores over var. *Sujata* of opium poppy which contains no erucic acid but 19% oleic acid, 56% linoleic acid and 3% linolenic acid (Table 3). Whereas the saturated fatty acids and to some extent erucic acid tend to cause loss of body weight and increase in blood cholesterol and size of adrenal gland[34], unsaturated fatty acids reduce the low density lipoprotein (LDL) by increasing the high density lipoprotein (HDL) in human blood. Thus, the non-narcotic var. *Sujata* of opium poppy makes a most viable oilseed crop which can successfully supplement the production of healthful vegetable oil for human consumption. Like 'Conola' (the rapeseed oil) or 'Linola' (the linseed oil), we may call this high value edible oil 'Sonola' (opium poppy var. *Sujata* oil) for commercial consumption.

Var. *Sujata*: A parental base for developing hyper-alkaloid CPS variety

The pharmaceutical/medicinal value of opium poppy is attributed to its opium containing the potent analgesic morphine, respiratory depressant codeine and antispasmodic papaverine alkaloids[9]. In CPS varieties, while opium is not gathered, major opium alkaloids (morphine, codeine and papaverine) are chemically extracted from the poppy straw as stated earlier. But the non-narcotic var. *Sujata* of opium poppy is devoid of both opium and opium alkaloids. Therefore, it attracted and rightly so, a searching remark 'Beer without alcohol'. An excellent medicinal plant, opium poppy, has been converted into a non-medicinal plant (seed poppy).

However, let us not become oblivious of the fact that on one hand, we intend to get rid of the opium-linked global evils and on the other, we wish to retain the pharmaceutical attributes of opium poppy. The novel var. *Sujata* might accomplish the first job neatly though not the second. But it can definitely serve as a base (parental) material for developing CPS chemotypes with specific alkaloids in straw, e.g. morphine⁺, codeine⁺, and papavarine⁺ CPS varieties. Such varieties would be the *true* CPS varieties as they would lack opium but have specific opium alkaloids accumulated in the capsule hulls (straw). They will thus meet both the above-mentioned requirements of opium poppy – being non-narcotic and pharmaceutically viable simultaneously. And if they also combine high yields of protein-rich seeds and unsaturated fatty acid-rich edible seed oil, it would be an unique example of 'killing four birds (not only two) with one stone'.

Now the question before us is – can we induce alkaloid biosynthesis and their accumulation in capsule hulls and keep the natural biosynthesis of opium (latex) restricted? A major bottleneck is the contention that latex carries enzymes required for the biosynthesis of alkaloids[3], i.e. without opium there cannot be alkaloid biosynthesis. Nevertheless there appears to be a silver lining.

Empirically we have observed that nature has evolved many *Papaver* species bearing latex but no alkaloids, such as *P. rhoes*, *P. orientale*, *P. argemone*, etc. on one hand, and *P. somniferum* with latex and alkaloids both, on the other. This offers a clue about the dichotomy of latex and alkaloid biosynthesis in opium poppy. Some reports are also available which reinforce our observation[2,35–37]. Thus, enzyme-systems operating for biosynthesis of latex and alkaloids perhaps independently, might help develop opium-less CPS chemotypes/varieties enriched with specific alkaloids in capsule hulls to meet pharmaceutical needs. The biogenetic pathway of phenanthrene isoquinoline alkaloids, mainly the narcotic morphine, codeine and thebaine has already been established[3] (Figure 2). Therefore, activating or inactivating/blocking of the enzyme activity at a specific site of the chain by appropriate mutagenesis may be a distinct possibility. We have already initiated a breeding programme following the double-faceted mutational and recombinational approaches to achieve the above goal[26].

Concluding remarks

The opium-less and alkaloid-free non-narcotic var. *Sujata* of opium poppy developed for the first time by us

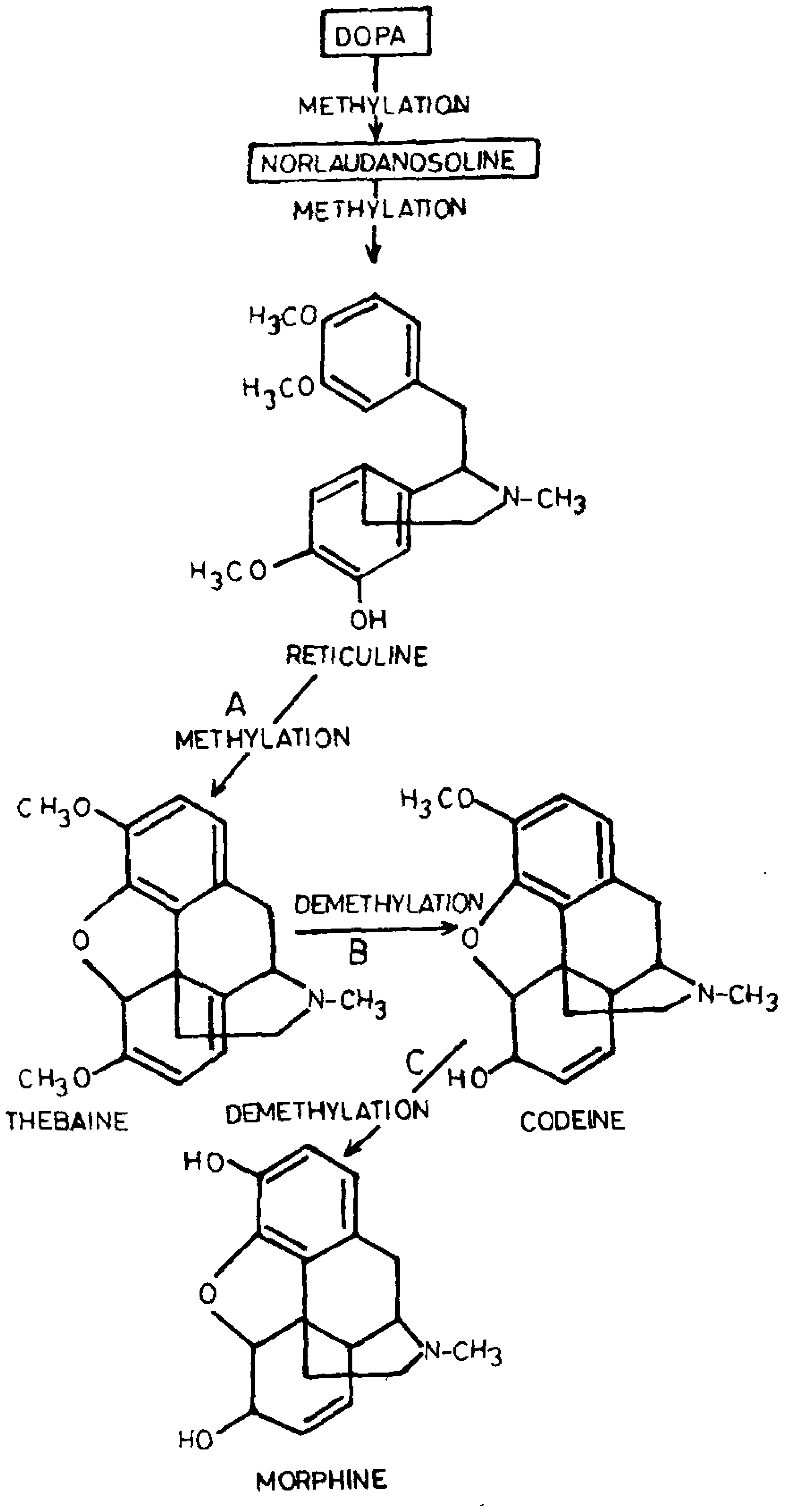

Figure 2. Biosynthetic pathway of phenanthrene alkaloids in opium poppy (A, B and C are the genes/enzymes involved in the process of bioconversion of opium alkaloids from thebaine → morphine).

(US patent application No. 09/276,720 dated 26 March 1999) is a breakthrough. It offers a cheap and permanent natural means of combating the global menace of opium abuse. Being a fine example of genetic conversion of narcotic 'opium poppy' into non-narcotic 'seed poppy', it is a potential seed crop and a viable supplement to oilseed crops. The oil being largely apportioned by unsaturated fatty acids provides a natural dietary control for CHD. Besides, seeds are not only rich in fatty acids but also in proteins, and hence are a good source of high calorie nutritive food, extensively used in culinary, confectionery and bakery industries. In contrast, seeds of mustard, the major oilseed crop of India, are not edible as food item, though their whole grains do have protein.

The current level of seed and oil yields of the opium poppy var. *Sujata* can be further improved by evolving more superior non-narcotic varieties – var. *Sujata* is only the forerunner. It can also be tailored into a 'designer crop' with specific unsaturated fatty acids (oleic/linoleic) and/or with specific straw-alkaloids (especially thebaine, morphine or codeine) as in case of rapeseed and mustard[38,39]. As far as the utility of seeds and seed oil is concerned, there is no problem with seeds as such in India. But, the problem is with poppy oil because our dietary habit is not yet tuned to its taste and flavour, unlike in Russia and other European countries. The oil and seeds might become good export commodity – a potential foreign exchange earner. Extensive cultivation and seed production should now be no bar with the non-narcotic var. *Sujata* of opium poppy.

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Human dimensions of climate change: Results of a survey of scientists and engineers

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The extent of scientific understanding and awareness about global climate change plays a crucial role in having informed public debate which is an essential input for decision-making in democratic societies. An opinion survey of more than one thousand scientists and engineers was undertaken to highlight their perception pertaining to: (i) Awareness about scientific understanding of various terms related to climate change; (ii) Environmental concerns and consequences; and (iii) Policy action for improvement of environment and satisfaction with environmental health status. The results of the survey are discussed in the paper.

RISE in atmospheric temperature witnessed in the second half of the eighties and the present decade is presumed to be the effect of global warming. There is a natural greenhouse effect which is already keeping the earth warmer than it would otherwise be[1]. The prominent greenhouse gases (GHGs) are carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide. Emissions of GHGs are causing substantial increase in their concentrations in the atmosphere. This increase would enhance the greenhouse effect, resulting in additional warming of the earth's surface. In recent years there has been a sharp increase in man-made emissions of GHGs. The pre-industrial concentration of carbon dioxide, in the atmosphere was about 280 ppmv and the present concentration about 360 ppmv (ref. 2). The sensitivity of the climate system to greenhouse gas forcing is not yet well known; the assessment – that an equilibrium warming of 1.5–4.5°C for a doubling carbon dioxide concentration in the atmosphere (or an equivalent mixture of greenhouse gases) – remains[3]. The rise in temperature can alter the global climate which may cause melting of polar ice caps, raise sea level, destroy the existing ecosystem and exert varied types of adverse effects on humankind. Recognizing the gravity of the impending crises, the global community has started deliberating on environmental protection and its relationship with economic development. The latter will have to be pursued in a sustainable mode. The global environmental concern came into sharp focus at the Rio Summit in 1992, where a framework convention on

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