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Probable Agricultural Biodiversity Heritage Sites in India: XI. The Upper Gangetic Plains Region

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Abstract

The Upper Gangetic Plain, the western part of the larger Gangetic Plains, has been one of the epicenters of origin and evolution of agriculture in India from the Neolithic period. The favorable climate and the landscape of the region have attracted the local people towards domestication of plants and animals. It led to evolution of settled agriculture from a nomadic pastoral life. The archaeological and literary (Vedic) evidences suggest it to be one of the regions where rice was first brought into cultivation from the wild, and where wheat was introduced through interactions with the Harappan civilization, followed with the domestication and introduction of a number of cereals, grain legumes, oilseed and other crops from other parts of the world involving most people from the early days. These crops were better exploited with improved cultivation practices, including the introduction of the plow. For these reasons, this region made faster economic progress compared with other regions, and evolved valuable genetic diversity in a wide range of crops. With increasing population, it expanded to other parts with new settlements and/or by sharing the knowledge gained and the products with other parts of the region, making India principally an agriculture-based economy. The economic prosperity of the region led to urbanization and establishment of the initially Hindu doctrine and way of life. Thus, the region can be considered the mother of much of agriculture in India and is being proposed as another National Agricultural Biodiversity Heritage Site, based on established indices.

The Gangetic Plain, watered by perennial rivers such as Ganga (Ganges), Yamuna, Ghagra, Gomati, Gandak, Son, and several tributaries with a long stretch of sedimental land, including the Upper Gangetic Plain (UGP), laid the foundations of agriculture in India by the early farming communities and can be considered the mother of much of agriculture practiced in other parts of the country. Over the ages, the Gangetic landscape with fertile soil and hospitable climate of river valleys and plains attracted most human settlers to the region, as these factors are fundamental to agricultural productivity and essential for the growth and development of agriculture and civilization. There is much evidence to suggest that agriculture in the Gangetic plains began with Neolithic settlements, evolved over times, and that it has been the main occupation of human populations in the region since then. The beginning of

agriculture in the region can be traced with evidence from Mahagara and Koldihwa (District Allahabad) in the Belan Valley (Tripathi, 2008).

The prevalent ecosystems, the land forms and the differential development, conditioned by limits of human intellect over time, divided the Gangetic plain into three regions – the upper, the middle, and the lower Gangetic plains. The UGP is comparatively drier and more arid, with climate being little more prone to extremes. It has by and large homogenous soil, with evidences of very early beginning of agriculture traced to the Neolithic period, engaging most people. It can share the credit for the earliest domestication of rice at Koldihwa and Mahagara, with Chopani Mando (District Allahabad, Belan river) of the Middle Gangetic Plain (MGP) in the same area, except China from where new evidences have risen in recent years (Tripathi, 2008). The region also had significant archaeological and other evidences for early cultivation of cereals, pulses, oilseeds, fruits, and vegetables. Further, there are evidences to suggest interaction with other early civilizations, for example, wheat cultivation was introduced into the region by the Painted Gray Ware (PGW) culture. It is quite likely that it entered into the region through Harappan interactions, as proven by the sites such as Bhagwanpura in Haryana or because of the movement of people from Harappan civilization towards the more fertile Ganga-Yamuna river valley, due to climatic changes in the Indus Valley. It is also suggested that due to favorable ecology and generation of superior technology, the PGW folk favorably exploited the land for greater yield and for a richer variety of agricultural products. Consequently, the UGP attained a superior economic growth in course of three to four centuries of PGW culture. Therefore, the region can be credited for evolving agriculture from the early stages of human settlement, domestication of rice, introduction of wheat from Harappan civilization, further domestication of plant and animal species, improved cultivation involving initial plowing technology, making agriculture the main economic activity, and dispersal of technologies and varieties of crops to other parts of the Gangetic plains, and the country at large with or without new settlements. During these developments, it evolved a large amount of genetic diversity in major cereals, pulses, oilseeds, and vegetable crops and practices like double cropping, etc. Culturally, it can be credited with the evolution of urbanization with emergence/ establishment of cities, and evolving and establishing the initial doctrines of the Hindu way of life. For these significant contributions to agriculture and culture, the region is being proposed to be another National Agricultural Biodiversity Heritage Site based on the indices illustrated by Singh and Varaprasad (2008).

Location and extent

The UGP region falls between the western Himalayas in the north and the hills and plateau in the south, and comprises the major portion of Haryana and Uttar Pradesh (UP). The Allahabad-Faizabad tract can be the dividing line between the Upper and Middle Gangetic plains (Tripathi, 2008). Ecologically, the northern plains

of Punjab, Haryana, and the western parts of eastern UP can be included into this region (Fig. 1). The region is bounded by the Himalayan subtropical pine forests, Terai-Duar savannas and grasslands and Himalayan subtropical broadleaf forests in the Himalayan foothills on the north, by the drier northwestern thorn scrub forests and Kathiawar-Gir dry deciduous forests in the west, by the Narmada Valley dry deciduous forests of the Malwa and Bundelkhand uplands on the south, and by the more humid MGP with grasslands and moist deciduous forests on the east (Fig. 1).

Administratively, it may include districts of northern Punjab, most of Haryana and western UP, and the districts such as Bareilly, Pilibhit, Lakhimpur Kheri, Sitapur, Hardoi, Sitapur, Barabanki, Lucknow, Unnao, Rae Bareilly, Kanpur, Kannuj of Central UP, and Allahabad, Pratapgarh, Sultanpur, Faizabad, Gonda, and Balrampur of eastern UP (Fig. 1). The important sites of the region with remains of ancient agriculture, which might have been the epicenters of origin and evolution of agriculture, include Lal Qila, Atranjikhera, Springpur, Hulas, Noh, Hastinapur, Radhan, etc.

Figure 1. Location and extent of the Upper Gangetic Plain (area marked by dotted line).

Landscape

The dominant landscape of the Gangetic Plains is a gentle slope. More than 95% of the ecoregion has been degraded or converted into agriculture with settlements of dense human population from thousands of years. Only the block running along the Himalayan foothills in UP remains protected. The landscape of the Gangetic Plains is sometimes classified into four divisions:

- The **Bhabar:** the areas adjacent to the foothills of the Himalayas, consisting of boulders and pebbles that have been carried down by the river streams. As the porosity of this belt is very high, the streams flow underground. The *bhabar* is generally narrow with its width varying between 7 and 15 km.
- The **Terai:** the area lying next to the *bhabar* region, composed of newer

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alluvium. The underground streams reappear in this region. The region is excessively moist and thickly forested. It also receives heavy rainfall throughout the year and is populated with a variety of wildlife.

- The **Bhangar:** the area consisting of older alluvium and forming the alluvial terrace of the flood plains. In the Gangetic plains, it has a low upland covered by laterite deposits.
- The **Khadar:** the area covering the lowland areas after the *bhangar*. It is made up of fresh newer alluvium which is deposited by the rivers flowing down the plain.

The *Terai* zone is dominated by moderate to gentle slopes. In the ancient times, thick vegetal cover, especially with moist deciduous forests covered the land. The plains are man-made, developed through deforestation. The region is predominantly watered and irrigated by the Ganga river system (Fig. 2), which consists of the network of the Ganga and Yamuna, the two major rivers with tributaries such as the Gomati. A host of streams rising out of the Shiwalik Range irrigate the western part of the plains. On the eastern side, there are Kalindi, Sukantha, Hindon, etc. Most of the rivers are perennial, providing hospitable land for human settlement. Because of these reasons the region is the most cultivable part of India.

Figure 2. The revered Ganga flowing through the Upper Gangetic Plain.

Agroclimate

The region is characterized as a hot subhumid ecoregion with alluvium-derived soil. The climate of the region is characterized by hot to warm summers and cool winters. It is relatively more prone to extremes. Winters could be frosty, especially in January, with hailstorms up to February, which often damages the crops. During these months, the temperatures at times drop down to 5–7°C. In summers, the temperatures go up to 45°C during May and June, when the rains start cooling the scorching heat of the

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summer. The region receives a mean annual rainfall of around 1,000 mm, of which 70% falls during the summer monsoon period extending from July to September. The monsoons are southwest originating in the Bay of Bengal. Therefore, the eastern reaches of the Middle and Lower Gangetic plains receive more moisture, with a gradual trend towards drier conditions in the west, the UGP. The rainfall during this period averages around 500 mm. The rainfall covers 70% of the evapotranspiration, extending the availability of moisture from 150 to 180 days (Sehgal *et al.,* 1992), which is the growing period for crops. The dry period is from February to June.

The soils of the region are generally deep loamy and have developed on alluvium. The dominant soil-scapes that represent the region constitutes gentle to very gentle sloping Ustochrepts, Haplustalfs, and Ustifluvents as per the soil classification. The *Terai* zone is dominated by the soil-scapes with moderate to gentle sloping Hapludolls and Hapludalfs. The moisture availability in these soils ranges from medium to high. The *Basiaram* (silt loam soils) and *Haldi* (sandy loam) series represents the soils of the plains and of the piedmont plains, respectively; the latter are rich in organic matter (Sehgal *et al.,* 1992).

The soils of the region are by and large homogenous with *usar* and *bhabar,* being the two dominant types, depending on the drainage pattern of the particular area. Other

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soils are *khadar* and *bhangar*. *Khadar* soils, rich in nutrients are found in the flood plains of river, generally with pH ranging between 6 and 8. *Bhangar* soil is more extensive in inter pluvial zones. The soluble salts are present in a smaller percentage. It is neutral to slightly acidic in reaction. The soils closer to Ganga are loamy to sandy-loamy in texture, while the Yamuna region has more silt composition. The *bhangar* soil is poor in phosphoric acid, nitrogen and other organic matters (Tripathi, 2008).

Floristic diversity

The region is rich in floristic diversity. In the ancient times, the land was covered with a thick vegetal of moist deciduous forests. According to ancient literary sources, the area between Saraswati and Sadanira was covered with thick forests such as Basundha, Naimisaranya, and Utpalaranya. *Sal*, *babool*, *khair*, *shisham*, *semal*, etc. were the common trees growing. Most of these plants have been testified from the excavations at Lal Qila, Atranjikhera, Hastinapur, etc.

The major natural vegetation in the region is tropical dry deciduous forests. The dominant tree species in the region are *khair* (*Acacia catechu* Brandis), *bael* [*Aegle marmelos* (L.) Correa ex Roxb.], *siris* [*Albizia lebbeck* (L.) Benth.], *bakli* [*Anogeissus latifolia* (Roxb.) Bedd], *palas* [*Butea monosperma*

(Lam.) Taub.], *amaltas* (*Cassia fistula* L.), *shisham* (*Dalbergia sissoo* Roxb.), *bargad* (*Ficus benghalensis* L.), *peepal* (*Ficus religiosa* L.), *haldu* [*Haldina cordifolia* (Roxb.) Ridsdale; syn. *Adina cordifolia* (Roxb.) Bra], *jamun* [*Syzygium cuminii* (L.) Skeels], *sal* (*Shorea robusta* C.F. Gaertn.), and *bahaera* [*Terminalia bellirica* (Gaertn.) Roxb.]. The important grass species are *kilikanal* (*Arundo donax* L.), *senr* [*Chrysopogon fulvus* (Spreng.) Chiov.], *jarakush* [*Cymbopogon martinii* (Roxb.) Wats.], *kush* (*Desmostachya bipinnata* Stapf.), *bhalai* [*Imperata cylindrica* (L.) P.Beauv.], *narkul* [*Phragmites karka* (Retz.) Steud.], *kans* (*Saccharum spontaneum* L.), and *khuskhus* (*Vetiveria zizanioides* L.). Based on the phytogeographical association, Rhind (2010) classified the forest vegetation into four categories.

I. Moist Deciduous Forests

These are the original forests dominated by *sal* (*Shorea robusta*), which form an upper canopy of trees reaching heights of up to 35 m. Other commonly associated trees include *Adina cordifolia, Dillenia pentagyna* Roxb., *Lagerstroemia parviflora* Roxb., *Stereospermum suaveolens* DC., *Terminalia bellirica*, and *T. tomentosa* Wight & Arn. However, today they remain only in the area extending along the Himalayan foothills of UP. In the Siwali Hills, canopy trees other than the ones mentioned above include *Anogeissus latifolia, Diospyros tomentosa* Roxb., *Garuga pinnata* Roxb., *Lannea coromandelica* (Houtt.) Merr., and *Pinus roxburghii* Sarg. Common second-story species are *Buchanania lanzan* Spreng., *Dendrocalamus strictus* Nees., *Ehretia laevis* Roxb., *Ougeinia oojeinensis* Hochr., and *Semecarpus anacardium* L.f., while typical third-story species include *Berberis asiatica* Griff., *Clerodendron viscosus* Vent., *Colebrookea oppositifolia* Lodd., *Murraya koenigii* (L.) Spreng., *Pogostemon plectranthoides* Desf., and *Woodfordia fruticosa* Kurz. Common shrub-layer species are *Chrysopogon fulvus, Heteropogon contortus* L., and *Thysanolaena maxima* (Roxb.) Kuntze, while herbs include *Bauhinia vahlii* Wight & Arn., and *Milletia extensa* (Benth.) Baker (syn. *M. auriculata* Baker ex Brandis). However, the physiognomy of these forests depends on various factors particularly relating to variations in local climate, topography, geology, and soil.

II. Tropical Moist Deciduous Riverine Forests

These forests occur on recent alluvium plains throughout the moist part of the Plains, particularly the sub-Himalayan zones of UP. These riverine areas are usually well drained but liable to erosion and flooding. So much of the well-established forest occurs on the higher and more stable alluvial terraces. The upper story typically includes *Adina cordifolia, Bombax ceiba* L. (syn. *B. malabaricum* DC), *Garuga pinnata, Gmelina arborea* Roxb., *Hymenodictyon excelsum* Wall., *Lagerstroemia parviflora, Lannea coromandelica*, and *Terminalia bellirica*. A few climbers and bamboos are also found. Common second-story species are *Cassia fistula, Dendrocalamus strictus, Ehretia acuminata* R.Br., *Emblica officinalis* Gaertn., *Holarrhena antidysenterica* Wall. ex A.DC., *Mallotus philippensis* (Lam.)

Müll.Arg., *Randia longispina* DC., and *Ziziphus mauritiana* Lam. (syn. *Z. jujuba* Mill.; *Z. vulgaris* Lam.). However, the trees in these forests rarely form extensive stands, and usually a shrub layer is well-developed. Typical shrubs include *Adhatoda vasica* Nees, *Callicarpa macrophylla* Vahl, *Glycosmis cochinchinensis* Pierre ex Engl., *Helicteres isora* L., *Murraya koenigii*, and *Podostemon plectranthoides*. In places, the shrub layer is so dense that few ground-layer species can exist and even grasses are often sparse or absent. Ground-layer species include *Cryptolepis buchanani* Roem. & Schult. and *Vallaris heynei* Sprengel.

III. *Sporobolus-Chloris* Saline Scrub

In these areas, there is restricted drainage combined with high summer temperatures and low monsoonal rainfall, and soils have high concentration of salts. The vegetation has an irregular, semi-savannah appearance, with *Acacia arabica* Willd. [syn. *A. nilotica* (L.) Delile] dominating the loamy soils, and *Butea frondosa* Roxb. ex Willd., the clayed waterlogged areas. *Azadirachta indica* A. Juss. is frequent and the palm *Phoenix sylvestris* (L.) Roxb. has a scattered distribution. At the ground level, the gregarious, perennial grass *Sporobolus pallidus* Benth. often dominates together with the annual grass *Chloris montana* Roxb., and the annual forb (non-grass herb) *Cyanotis axillaris* (L.) D.Don. However, many of the characteristic species have sporadic distributions, which include *Aeschynomene indica* L., *Alysicarpus bupleurifolius* (L.) A.DC., *Aneilema nudiflorum* Miq. ex C.B.Clarke, *Corchorus acutagulus* Lam., *Cyperus aristatus* Hook.f. & Thoms. Partim ex C.B.Clarke, *Oldenlandia diffusa* Roxb., *Portulaca oleracea* L., *P. tuberosa* Roxb., and the grasses such as *Aristida hystrix* Linn.f., *Desmostachya bipinnata* (L.) Stapf., and *Paspalidium flavidum* (Retz.) A. Camus. In hollows and shallow depressions where rainwater can accumulate "wild paddies" often develop, characterized by species such as *Echinochloa colonum* L., *Ischaemum rugosum* Salisb., and *Paspalum scrobiculatum* L.

IV. *Phragmites-Saccharum-Imperata* Grassland

These grasslands are found throughout the Gangetic Plain, from Punjab to the Brahmaputra Valley. They are characteristic of low-lying, poorly drained land with higher water tables. The typical perennial grasses are *Imperata cylindrica* (L.) P.Beauv., *Phragmites karka* (Retz.) Steud., and *Saccharum* L. species, such as *S. arundinaceum* Retz. (syn. *S. procerum* Roxb.), *S. bengalense* Retz., and *S. spontaneum*. Other perennial grasses represented throughout this formation include *Bothriochloa intermedia* (R.Br.) A.Camus, *B. odorata* (Lisboa) A.Camus, *Chrysopogon aciculatus* (Retz.) Trin., *Cynodon dactylon* Pers., *Desmostachya bipinnata, Hymenachne pseudointerrupta* Müll.Hal., *Ischaemum timorense* Kunth, *Narenga porphyrocoma* Bor., *Neyraudia reynaudiana* (Kunth) Keng ex Hitchc., *Panicum notatum* Retz., *Sclerostachya fusca* A.Camus, *Sporobolus indicus* (L.) R.Br., and *Vetiveria zizanioides*. Typical annual species are *Apluda mutica* L., *Chionachne koenigii* (Spreng.) Thwaites & Hook.f., *Dactyloctenium aegyptium*

(L.) K.Richt., *Echinochloa colonum, Eragrostis viscosa* Scribn., *Ischaemum rugosum* Salisb., *Microstegium ciliatum* A.Camus, *Paspalum scrobiculatum*, and *Schizachyrium brevifolium* (Sw.) Nees ex Büse. In addition to grasses, over 50 species of herbaceous forbs have also been recorded. These include *Alysicarpus monilifer* (L.) DC., *Blumea membranacea* DC., *Euphorbia hirta* L., *Hyptis brevipes* Benth., *Kyllinga brevifolia* Rottb., *Leucas aspera* Link, *Lindernia crustacea* (L.) F.Muell., *Lochnera rosea* Rchb., and *Mikania scandens* Willd. However, in very swampy areas, the reed *Phragmites karka* can become mono-dominant covering 90% of the areas.

Agriculture and agrobiodiversity

The agriculture in the region is very old, dating back to the Vedic Age [1,500–600 BCE; 8000–1000 BCE (editors)] and before, which saw the development of agricultural activities on a large scale. The people of the early phase were semi-nomadic and subsisted on large herds of domesticated cattle and farm animals. They moved their settlements from one pastoral area to another and lived on agrarian and dairy products obtained from cattle. As their requirements grew, they brought large tracts of fertile land under the plow, driven by oxen. Therefore, agriculture or farming has been the mainstay of the people of this region from time immemorial; in fact, the region has been the epicenter of origin and evolution of agriculture due to the availability of water for the most part of the year from rains, and the network of tributaries of major rivers (that later evolved into the canal system). For this reason, traditional farming practices relate to both rainfed and irrigated agriculture. The region is often referred as a granary or the bread-basket of India.

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Rice was domesticated in the region, and wheat domesticated early suited well to the dry winter climate. Therefore, most of the farming and cropping systems that evolved revolve around these two crops. During the rainy (*kharif*) season, the common crops grown in the area are rice, maize, and pigeonpea, and during the postrainy cold (*rabi*) season, wheat, chickpea, rapeseed mustard, and vegetables are grown. Sugarcane is cultivated as a post-*rabi* crop during November–December and February–March. The post-*rabi*, summer crops include short-duration pulses such as *Vigna* spp. and vegetables such as cucurbits, which are also cultivated in river beds.

Rice is the main *kharif* crop, traditionally cultivated in the eastern districts of the UGP (Fig. 3). The alternate crops are

maize, sorghum, pulses, sugarcane, and groundnut. Traditionally, wheat–chickpea based cropping patterns were main *rabi* crops in the areas of northwestern districts of UP and Haryana. The network of canals in Punjab, Haryana, and northwestern districts of UP support irrigated wheat crops (Fig. 4). The alternative important *rabi* crops are maize, sugarcane, and groundnut. The *kharif* maize has the largest area in UP, with alternate crops as rice in *kharif* and wheat in *rabi*. However, in some areas, groundnut, sugarcane, finger millet, and pulses are the alternate crops. Hence, the major crops of the region are rice, maize, pearl millet, wheat, barley, sorghum, chickpea, pigeonpea, lentil, black gram, green gram, pea, rapeseed mustard, sunflower, groundnut, linseed, cotton, sugarcane, potato, vegetables, etc.

The major cropping systems are rice–wheat, which brought about the Green Revolution in the region. Other cropping systems are sorghum–wheat, sugarcane–wheat, cotton–wheat, pearl millet–rapeseed mustard, maize–wheat, maize–wheat–green gram, pigeonpea–wheat, groundnut–wheat, rice–chickpea, rice–lentil, rice–mustard, rice–fallow–fallow, rice–fallow–rice, potato–black gram/green gram, etc. Presently, of the 77 cropping systems practiced, 38 are rice-based. About 7% of the area is covered by 5 single-crop systems; 72% of the area by 56 double-crop systems; and the remainder 21% by 16 triple-crop systems.

Figure 3. Irrigated agriculture of the Upper Gangetic Plain.

Figure 4. Wheat crop in the Upper Gangetic Plain. (Source: green.blogs.nytime.com)

In addition, to ensure the availability of diverse food, mixed cropping is also a part of traditional agricultural cropping systems, which include vegetable crops. For example, the planting of *Cucumis melo* var. *momordica* or *C. sativus* mixed with maize and pearl millet is a common constituent of subsistence agriculture.

Crop–livestock interaction has been a unique feature of the region, and there has been a tradition of using crop residue as the main fodder for livestock. For example, wheat straw is the most preferred feed for animals, which may be supplemented with pulse peels and oilcake. Livestock has a major input in crop production by providing all the energy required to perform most operations/activities.

Representative species in various crop groups

Cereals, pseudocereals, and millets. Amaranth (*Amaranthus hypocondriacus* L.), barley (*Hordeum vulgare* L.), buckwheat (*Fagopyrum emarginatum* Moench), foxtail millet [*Setaria italica* (L.) Beauv.], kodo millet (*Paspalum scrobiculatum* L.), maize (*Zea mays* L.), oat (*Avena sativa* L.), pearl millet [*Pennisetum glaucum* (L.) R.Br.], proso millet (*Panicum miliaeceum* L.), *ragi* or finger millet (*Eleusine coracana* Gaertn.), rice (*Oryza sativa* L.), sorghum [*Sorghum bicolor* (L.) Moench], and wheat (*Triticum aestivum* L.).

Grain legumes and oilseeds. Black gram [*Vigna mungo* (L.) Hepper], chickpea (*Cicer arietinum* L.), cluster bean [*Cyamopsis tetragonolobus* (L.) Taub.], garden pea (*Pisum sativum* L.), green gram [*Vigna radiata* (L.) Wilczek var. *radiata*], lablab bean [*Lablab purpureus* (L.) Sweet ssp. *benghalensis* (Jacq.) Cufod.], lentil (*Lens culinaris* Medic), moth bean [*Vigna aconitifolia* (Jacq.) Marechal], pigeonpea [*Cajanus cajan* (L.) Millsp], rapeseed mustard [*Brassica juncea* (L.) Hook.f. & Thomson; *B. napus* L.; *B. rapa* L. var. *brown sarson*; *B. rapa* L. var. *yellow sarson*; *B. campestris* L.; *B. tournefortii* Gouan], safflower (*Carthamus tinctorius* L.), sweet pea (*Lathyrus odoratus* L.), and taramira (*Eruca sativa* Mill.).

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Fodder and fiber crops. Cluster bean (*Cyamopsis tetragonolobus*), cowpea [*Vigna unguiculata* (L.) Walp.], deenanath grass (*Pennisetum pedicellatum* Trin.), *Ficus auriculata* Lour., *F. semicordata* Buch.-Ham. ex Sm., *Grewia optiva* J.R. Drumm. ex Burret., guinea grass (*Panicum maximum* Jacq.), *gular* (*Ficus racemosa* L.; syn. *F. glomerata* Roxb.), *Lathyrus aphaca* L., *Leucaena leucocephala* Lamk., levant cotton (*Gossypium herbaceum* L.), napier grass (*Pennisetum purpureum* Schumach.), oat (*Avena sativa*), rhodes grass (*Chloris dolichostachya* Lag.), *Sesbania sesban* (L.) Merr., *Trifolium resupinatum* L., tula cotton (*Gossypium arboreum* L.), and velvet bean [*Mucuna deeringiana* (Bort.) Merr.]. In addition, crop residues of major and minor cereals and their forage types are used as fodder.

Vegetables. Ash gourd [*Benincasa hispida* (Thunb.) Cong.], *bhindi* or okra [*Abelmoschus esculentus* (L.) Moench], bitter gourd (*Momordica charantia* L.; *M. balsamina* L.), bottle gourd [*Lagenaria siceraria* (Molina) Standley], brinjal (*Solanum melongena* L.), brussels sprouts (*Brassica oleracea* var. *gemmifera* Zenker), cabbage [*Brassica oleracea* var. *capitata* (L.) DC.], cauliflower (*Brassica oleracea*

var. *botrytis* L.), cucumber (*Cucumis sativus* L.), *kachari* (*Cucumis melo* var. *agrestis* Naud.), *kakri* (*Cucumis melo* var. *utilissimus* Duthie and Fuller), *kohlrabi* (*Brassica oleracea* L. var. *gongylodes* L.), *mitha kumra* (*Cucurbita maxima* Lam.), muskmelon (*Cucumis melo* L.), *phut* or snap melon (*Cucumis melo* var. *momordica* Duthie and Fuller), pumpkin [*Cucurbita pepo* L.; *Cucurbita maxima* Duchesne], rape (*Brassica napus* L.), *ras dhana* (*Amaranthus caudatus* L.), ridge gourd [*Luffa acutangula* (L.) (Roxb.], round gourd or *tinda* [*Praecitrullus fistulosus* (Stocks) Pangalo; syn. *Citrullus fistulosus* Stocks; *C. lanatus* var. *fistulosus* (Stocks) Duthie & J.B.Fuller], *satawar* (*Asparagus racemosus* L.), sponge gourd (*Luffa cylindrica* Roxb.; syn. *L. aegyptiaca* Mill.), and tomato (*Solanum lycopersicum* L.; syn. *Lycopersicum esculentum* Mill.).

Leafy vegetables. *Bathua* (*Chenopodium album* L.), *chaulai* (*Amaranthus paniculatus* L.), garden lettuce (*Lactuca sativa* L.), green vegetable [*Beta vulgaris* L. var. *orientalis* (Roth) Moq.], *lal sag* (*Amaranthus gangeticus* L.), *faridbutti* used as pot herb (*Farsetia hamiltonii* Royle*, F. jacquemontii* Royle), *latmhuria* or leafy pot herb [*Digera muricata* (L.) Mart.], *methi* or fenugreek (*Trigonella foenum-graecum* L.), mustard green [*Brassica juncea* (L.) Czern. var. *integrifolia* (H. West) Sinskaya], spinach (*Spinacia oleracea* L.), and water spinach (*Ipomoea aquatica* Forsk.).

Rhizome, tubers, and bulbs. *Arbi* or *arvi* [*Colocasia esculenta* (L.) Schott], carrot (*Daucus carota* L.), *lahsan* or garlic (*Allium sativum* L.), *jimikand* or Indian yam (*Dioscorea trifida* L.f.; *D. bulbifera* L.), *kand* (*D. kalkapershadii* Prain & Burkill.), *kanda* or shallot (*Allium ascalonicum* L.; syn. *A. cepa* L. var. *aggregatum*), onion (*Allium cepa* L.), potato (*Solanum tuberosum* L.), radish (*Raphanus sativus* L.), and *shakarkand* or sweet potato [*Ipomoea batatas* (L.) Lam.].

Fruits. *Anjir* (*Ficus carica* L.; *F. palmata* Forsk.), *aonla* (*Emblica officinalis* Gaertn.), *bael* (*Agle marmelos*), *ber* (*Ziziphus oenoplia* Mill.), *ber* or European nettle tree (*Celtis australis* L.), guava (*Psidium guajava* L. Links), jackfruit (*Artocarpus heterophyllus* Lam.), *jamun* [*Syzygium cuminii* (L.) Skeels], *kaiphal* (*Myrica esculenta* Buchanan-Hamilton ex D. Don), *karaunda* (*Carissa carandas* Lour.), karna orange (*Citrus karna* Raf.), *khejri* (*Prosopis cineraria* Druce.), kinnow (*Citrus deliciosa* Ten.; syn. *C. reticulata* Blanco.), *kondai* or parker [*Flacourtia indica* (Burm.f.) Merr.; syn. *F. sepiaria* Roxb.], krape (*Citrus paradisi* Macfad.), litchi (*Litchi chinensis* Sonn. Mill.), mango (*Mangifera indica* L.), *shahtoot* or mulberry (*Morus alba* L.; *M. nigra* L.), orange (*Citrus sinensis* L. Osbeck), *papeeta* or papaya (*Carica papaya* L.), *Perilla ocymoides* L., *phalwara* [*Aesandra butyracea* (Roxb.) Baehni], pomegranate (*Punica granatum* L.), *pureni* [*Ampelocissus latifolia* (Roxb.)

Crop–livestock interaction has been a unique feature of the region, and there has been a tradition of using crop residue as the main fodder for livestock.

Planch.; syn. *Vitis latifolia* Roxb.], *galphuli* or salpan (*Flemingia chappar* Benth.), *sansaru* [*Debregeasia hypoleuca* (Hochst.) Wedd.], tamarind (*Tamarindus indica* L.), watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai], and wood apple (*Feronia elephantum* Correa; syn. *Limonia acidissima* L.).

Spices. *Benarasi rai* or black mustard [*Brassica nigra* (L.) Koch.], coriander (*Coriandrum sativum* L.), *curry patta* (*Murraya koenigii* Spreng.), fennel (*Foeniculum vulgare* Mill.), *lal mirchi* (*Capsicum annuum* L.), *pudina* (*Mentha arvensis* L.), and turmeric (*Curcuma domestica* Valet.; syn. *C. longa* L.).

Other crop species. Indigo (*Indigofera tinctoria* L.), *rasna* (*Pluchea lanceolata* Oliv. & Hiern), and sugarcane (*Saccharum officinarum* L.).

Medicinal plants. *Adusa* (*Adhatoda zeylanica* Medik.), aloe (*Aloe barbadensis* Mill.), *arandi* or castor (*Ricinus communis* L.), *ashwagandha* [*Withania somnifera* (L.) Dunal.], *babchi* [*Psoralea corylifolia* L.; syn. *Cullen corylifolium* (L.) Medik.], basil (*Ocimum sanctum* L.), *behada* (*Terminalia bellirica*), *bael* (*Aegle marmelos*), *chitraka* (*Plumbago zeylanica* L.), *datura* (*Datura stramonium* L.), false amaranth (*Digera muricata* Mart.), *giloe* [*Tinospora cordifolia* (Willd.) Hook.f. & Thomson], Indian madder [*Rubia manjith* Roxb. ex Flem.; syn. *R. cordifolia* L., *Sesbania cannabina* (Retz.) Pers.], *kalmegh* (*Andrographis paniculata* Nees), *karihari* (*Gloriosa superba* L.), lemongrass [*Cymbopogon martinii* (Roxb.) Wats.], *mentha* (*Mentha piperita* L.), *mustu* (*Lactuca remotiflora* DC.), opium (*Papaver somniferum* L.), *rasana* (*Pluchea lanceolata*), rose (*Rosa damascena* L.) cultivated extensively in Aligarh, Sikanderabad, and Kannooj, *satawar* (*Asparagus curillus* Buch.-Ham. ex Roxb.; *A. sarmentosus* L.), *shalaparni* [*Desmodium gangeticum* (L.) DC], *vach* (*Acorus calamus* L.), and velvet bean [*Mucuna pruriens* (L.) DC.].

Timber. *Babool* [*Acacia arabica* Willd.; syn. *A. nilotica* (L.) Delile], *dhau* (*Anogeissus latifolia*), *khair* (*Acacia catechu*), red cedar (*Toona ciliata* M.Roem.), *neem* (*Azadirachta indica*), *sal* (*Shorea robusta*), *semal* (*Bombax ceiba* L.), and *shisham* (*Dalbergia sissoo*).

Multipurpose species. Buel *(Grewia optiva), chironji* (*Buchanania lanzan*), date palm [*Phoenix robusta* (Becc.) Hook.f.], *Indopiptadenia oudhensis* (Brandis) Brenan, *khair* (*Acacia catechu*), *mahua* (*Madhuca indica* J. F. Gmel.; syn. *M. longifolia* Macbride), *palas* (*Butea monosperma*), *pongam* [*Pongamia pinnata* (L.) Pierre], *siris* (*Albizia lebbeck*), and *Thysanolaena maxima* (Roxb.) Kuntze (brooms).

Gum- and resin-yielding plants and forest products. Because of high crop productivity, there is less dependence on forest products. However, in areas around the forests, the local people do harvest food, folk medicines, fodder, fuel, and variety of other plant species, yielding products such as dyes, tannins, gum, fibers, resin, etc.

Wild relatives of crop species. Arora and Nayar (1984) recorded the following wild relatives of crop plants from the

region: *Abelmoschus tuberculata* Pal & Singh, *Amaranthus spinosus* L., *Brassica quadrivalis* Hook.f. & Thorn., *Chenopodium album* L., *Cichorium intybus* L., *Coccinia indica* Wight & Arn., *Cochorus trilocularis* L., *Cucumis satosus* Cogn., *Grewia asiatica* Mast., *Hibiscus surathensis* L., *Lathyrus aphacea* L., *Lepidium draba*, *Luffa echinata* Roxb. var. *longistylis* (Edur.) Clarke, *Paspalum scrobiculatum* L., *Saccharum longisetosum* (And.) Narayanaswami ex Br., *Sclerostachya fusca* Roxb., *Setaria sphacelata* (Sch.), *Trigonella polycerata* L., and *Urena repanda* Roxb. ex Sm. In addition, the following other wild relatives have been recorded in the region: *jangli bhindi* [*Abelmoschus cancellatus* (L.f.) J.O. Voigt; syn. *A. crinitus* Wall.; *A. manihot* (L.) Medik.], *Allium stracheyi* Baker, *Amaranthus polygamus* L., *Asparagus curillus*, *A. sarmentosus*, *Atylosia scarabaeoides* (L.) Benth. (used as pot herb), *Carissa spinerum* L., *Carthamus oxycantha* Bieb., *Chenopodium murale* L., *Corchorus acutagulus, Curcuma ferrugenea* Roxb., *C. leucorhiza* Roxb., *Dioscorea deltoidea* Wall. ex Griseb., *Echinochloa colonum*, *Indigofera caerulea* Roxb. var. *caerulea, Indigofera gangetica* Sanjappa, *I. thothathri* Sanjappa, *Momordica balsamina* L., *Oryza rufipogon* Griff., *Panicum notatum*, *Phoenix paludosa* Roxb., *P. sylvestris*, *Saccharum arundinaceum, S. bengalense, S. spontaneum, Trigonella corniculata* L. (syn. *T. balansae* Boiss. & Reut., *T. obcordata* Benth., *T. occulta* Ser.), *Vigna prainiana* Babu & S.K.Sharma, and *V. radiata* var. *sublobata* (Roxb.) Verdc.

Endemic species. Being open and spread over, the Gangetic plains are poor in endemism. Only a few species can be considered endemic, such as *Carex myosurus* Nees var. *oraestans* (C.B. Clarke) Kuek, *Derris scandens* Benth. var. *saharunpurensis*, *Indigofera gangetica, I. thothathri, Indopiptadenia oudhensis*, and *Praecitrullus fistulosus*. Table 1 summarizes the representative endemic species of the region.

Table 1. Representative species endemic to the Upper Gangetic Plain: parts of Punjab, Haryana, and Uttar Pradesh.

Plant species	Family	Habit	Distribution	Remarks
Derris scandens var. *saharunpurensis*	Fabaceae	Woody vine	Terai region	Medicinal
Indigofera gangetica	Fabaceae	Herb	Upper Gangetic Plain	Genetic resource
Indigofera thothathri	Fabaceae	Shrubs	Uttar Pradesh	Genetic resource
Indopiptadenia oudhensis	Mimosaceae	Small tree	Eastern Uttar Pradesh	Fuel wood and fodder
Praecitrullus fistulosus	Cucurbitaceae	Trailing vine	Western Uttar Pradesh, Haryana	Vegetable

Threatened species. Nayar (1996) reported plant species such as *Albizia thompsonii* Brandis, *Carex myosurus* Nees var. *oraestans* (C.B. Clarke) Kuek., *Carum villosum* Haines, *Ligusticum albo-alatum* Haines to be under various levels of threat. But now, because of various anthropological pressures, a number of species are under threat. As per a recent study in the Gangetic Khadar region, identified as one of the most vulnerable areas, a large number of species have been found missing. They included *Bacopa monnieri* (L.) Pennell, *Hygrorhiza aquatica*, *Coix lacryma-jobi*, *Sisymbrium irio* L., *Capparis zeylanica* Roxb., *Hypericum japonicum* Thunb., *Crotalaria orixensis* Willd., *Alternanthera philoxeroides* Griseb., *Polygonum plebejum* var. *sindica*, *Rumex crispus* L., and *Mallotus philippensis* (Lam.) Müll.Arg. (Khan *et al*., 2008). Recently, Prakash *et al.* (2010) reported *Indopiptadenia oudhensis* to be under threat, and the Ministry of Environment and Forests (Government of India), reported several more species, such as *Arenaria curvifolia* Majumdar, *Brachystelma laevigatum* Hook.f., *B. pauciflorum* Duthie, *Ceropegia bulbosa* Roxb., *Cymbopogon flexuosus* (Nees ex Steud.) Watson, *Diospyros holeana* Gupta & Kanjilal, *Hemarthria hamiltoniana* Steud., *Indigofera thothathri* Sanjappa, and *Rauvolfia serpentina* (L.) Benth. ex Kurz to be under threat, in their recent press release (PIB Press Release, 2010). Some representative species under threat are listed in Table 2.

In addition, to the above plant species, several animal species of economic and environmental value are under threat of extinction, such as the Ganges river dolphin (*Platanista gangetica* Lebeck; Roxb.), *Ganges* shark (*Glyphis gangeticus* Müller & Henle), swamp deer (*Rucervus duvaucelii* Cuvier), etc.

Associated culture and tribes

According to the German indologist Max Müller, Aryan tribes migrated to the Indian subcontinent and spread into the UGP. He believed that they soon mingled with the local people and adapted to an agrarian way of life after settling down in small, organized communities. However, archaeological evidence and scientifically authenticated Vedic literature suggest continuity from the Saraswati Valley and Harappan (Indus Valley) or Indus Sarasvata civilization to the Ganga Valley (Vedic or Indo-Gangetic) civilization. These sources also suggest that Aryans were local people, as no archaeological evidences related with Aryan culture are found anywhere else, except India (Swami, 2008). In the Vedic Age [(1,500–600 BCE; 8000–1000 BCE (editors)], Aryans established four scriptures of knowledge called the Vedas: the Rig Veda, the Sama Veda, the Yajur Veda, and the Atharva Veda. These collections of hymns, with their social, religious, and philosophical doctrines, laid the foundation of the Hindu way of thought, life, and the religion. Aryans settled down as full-time farmers and brought large tracts of fertile land of the region under the plow. Based on profession, they classified the society into four main castes: Brahmins, Kshatriyas, Vaishyas, and Shudras.

The tribal communities in the region are not large. There are other communities, comprising the backward classes, scheduled

Table 2. Representative species under threat in the Upper Gangetic Plain: parts of Punjab, Haryana, and Uttar Pradesh.

Plant species	Family	Habit	Threat level[1]	Use
Albizia thompsonii	Fabaceae	Tree	R	Wood
Bacopa monnieri	Scrophulariaceae	Herb	R	Ayurvedic medicine
Brachystelma laevigatum[2]	Asclepiadaceae	Herb	VU	Attractive foliage
Brachystelma pauciflorum[2]	Asclepiadaceae	Herb	EN	Food
Carex myosurus var. *oraestans*	Cyperaceae	Herb	EN	Fodder
Capparis zeylanica	Capparaceae	Shrub	R	Medicinal
Ceropegia bulbosa[2]	Asclepiadaceae	Tuberous herb	VU	Food
Coix lacryma-jobi	Poaceae	Grass	R	Food grain
Crotalaria orixensis	Fabaceae	Perennial herb	R	Crotaorixin, genetic resource
Cymbopogon flexuosus[2]	Poaceae	Grass	EN	Lemongrass
Diospyros holeana[2]	Ebenaceae	Tree	VU	Timber
Hemarthria hamiltoniana[2]	Poaceae	Grass	EN	Grass
Indigofera thothathri[2]	Leguminosae	Shrub	VU	Genetic resource
Indopiptadenia oudhensis	Mimosaceae	Tree	EN	Fodder, fuel wood
Mallotus philippensis	Euphorbiaceae	Tree	R	Dye, medicinal
Polygonum plebejum var. *sindica*	Polygonaceae	Herb	R	Medicinal
Rauvolfia serpentina[2]	Apocynaceae	Shrub	VU	Medicinal
Rumex crispus	Polygonaceae	Perennial herb	R	Medicinal
Sisymbrium irio	Brassicaceae	Herb	R	Mustard genetic resource

1. EN = Endangered; R = Rare; VU = Vulnerable.
2. Notified by the Ministry of Environment and Forests (MoEF), Government of India.

castes and scheduled tribes. The scheduled castes and tribes live in rural areas and are mostly dependent on agriculture, forming the landless labor class. The Government of India has recognized five of the tribal communities as disadvantaged scheduled castes: Tharus, Bhoksas, Bhotas, Jaunsaries, and Rajis. Being both Rajputs and Brahmins, the Jaunsari tribe occupies the major portion, and mostly work as laborers in fields, farms, and forests. Other tribes such as the Kolis, Koisor Koltas, Aujis, and Doms are known by the name Harijans. The Terai-Bhabar area is concentrated with the Bhoksas and

the Tharus, while the southern areas are populated by tribes such as the Agaria, Bhumiyar, Bhil, Chero, Gond, Kol, etc. Along with the Tharus and the Bhoksas, there are some other tribes who trace their origin from the Mongoloids and the Khasas of the Himalayan region belonging to the Indo-Aryan stock. The Bhils and the Saharujas belong to the Indo-Dravidian lineage, and the Gonds and Kols belong to Munda-Dravidian stock. Koltas till the land for the Khasa tribe. The Haryana region mostly belongs to the Indo-Aryan and Indo-Dravidian tribes and includes several allied agricultural communities, the major ones being the Jats, Rajputs, Ahirs, Rors, Gujjars, etc.

Technology and products

Being one of the centers of origin and evolution of agriculture, the UPG region has made immense contributions to global agriculture both in terms of products and technology. The region can be credited with the earliest domestication of both plant and animal species and farming, beginning with Neolithic settlements around 2,000 BCE. The beginning of agriculture in the region can be traced with evidence from Mahagara and Koldihwa in Allahabad at the Belan Valley, where cultivated rice grains belonging to the Neolithic period were identified (Sharma, 1980). Subsequently, in the early Iron Age, the region was colonized by the Ochre-Colored Pottery culture. During this phase, it has been found to be associated with rice, barley, chickpea, and *khesari* dal, which were identified by Chowdhary (1983) in excavations at Atranjikhera (UP). Although, the people of that time were mainly food gatherers and growing of agricultural crops was an experiment, it reflected their ingenuity and desire to progress into settled agriculture (Chowdhary, 1983).

During the Iron Age, wheat cultivation was introduced into the region by the PGW culture. Wheat grains of *Triticum compactum* Host. without husk were collected from Atranjikhera. Wheat was also found at Hulas in UP and Mohrana in Punjab. This suggests that wheat entered in the region through interactions with Harappans. This is also well proven by the findings at sites such as Bhagwanpura in Haryana, which reveal the ingenuity and desire of the local people even in early times, for improving their agriculture with the introduction of potentially valuable food crops from other regions. It is worth mentioning that wheat discovered at these sites was *Triticum compactum*, and not the *T. aestivum* L. that is generally found in the MGP (Saraswat, 1994). In these excavations, it was further revealed that significant improvement was made in farming of the wheat crop to obtain high yields, a proof of the contributions of the local people in improving production technologies.

In subsequent periods, even legumes were cultivated. The literary evidences from the Vedic period that was contemporary with PGW, mention several cereals, such as *yava* (barley) and *dhanya* (paddy) with breeds like *plasuka* (fast growing), *sali*, *vrihi swastika* (*sathi*), etc. *Upvaka* (barley), *godhum* (wheat), *syamaka* (millet), and other crops such as *masa* (lentil), *khalakula* (*kulthi*), *khalva*, *mudga* (*munrga*), *kulmasa*

(*urad*), sesame (*til*), and *bajra* (millet) also find mention. Incidentally, these crops are also identified in archaeological remains. Some other edible species mentioned in these texts are *urvaru* and *urvauka* (cucumbers), *garmut* (wild beans), *karakandhu*, *kavala*, and *badara* (jujube). In addition, there appear several other plant names, such as *am*, *amla*, *gavindhuta*, *nimbi*, *priyangu*, *masusya*, and *saya* (Sharma, 1983), reflecting the contributions of local people in discovering plants with food and nutritional value. Further, this also means that even in those early days the people were consuming a variety of grains and food items. Archaeological and literary evidences also indicate the circulation of many wild varieties of beans and millets, suggesting the contribution of local people in introduction of plant species. The variety of crops also suggests the practice of double-cropping right from 1,000 BCE.

As the region was more suitable, ecologically, for wheat cultivation, it developed technological skills needed for the cultivation of this crop. The relatively dry and sandy soil of the region could be plowed even with wooden plowshares; however, there are evidences to prove the use of the iron plowshare, suggesting the existence of plow cultivation in the region during 1,000–800 BCE. Thus, due to the favorable ecology and knowledge of superior technology, the PGW folk of the region were able to exploit the land for greater yield, and richer varietal products of wheat, and attained superior economic gains.

During the early urban culture, a new crop of pulses (*Phaseolus mungo* L.) appeared in the region. At Radhan in Kanpur (Lal, 1984), wheat, barley, pea and an unidentified cotyledon of legumes were found. During the Northern Black Polished Ware period, newer settlements came up in the entire Gangetic Plains, extending the culture and agriculture to other parts of the subcontinent, leading to its expansion into the Nepalese *Terai* region in the northeast, to Taxila and Udegram in the west, to Brahmagiri-Amaravati-Ter in the south, and across the peninsula from Gujarat, Saurashtra (Prabhas Patan) in the west to Chandraketugarh in Bengal in the east. The period of 600–300/200 BCE was the age of consolidation of power in the entire Gangetic Plains. This gradually brought a large number and rich variety of agricultural implements into practice.

Thus, the fertile Gangetic Plains with plenty of water resources became the center of cultivation of a number of plant species, and the recipient of introduced crop diversity from Central Asia and Africa, especially of cereals, legumes, vegetables, and oilseeds from the early times. These crop species, through adaptations and selections in time and space over the millennia, evolved into large genetic diversity as new varieties and cultivars adapted to different agroecological zones of the Gangetic Plains, converting the region into an important center of diversity. In rice, the region is known for variability for drought tolerance, deep-water floating types, scented rice, etc. For example, the winter variety *Agahani* and the group of varieties called *Usar* are well known for salt tolerance and have been used in breeding programs. In non-aromatic rice, cultivars such as *Adamchini*, *Anjee*, *Bambasa*,

Bansi, *Dehula*, *Jaisuria*, *Jalamonga*, N22, NP130, *Tapachini*, T100, T136, and *Jhona* (Haryana) are commonly known. In aromatic rice, *Basmati*, *Duniapet*, *Hansraj*, *Kala Namak*, *Kalasukhdas*, *Lalmati*, *Sakkarchini*, *Tilakchandan*, and *Vishnuparag* are commonly known. Some of the valuable traditional varieties with aroma, such as *Kala Namak*, evolved with resistance to soil salinity (Siddiq *et al*., 2006). Drought tolerance landraces are known from Nagina. Similarly, in wheat, traditional cultivars such as *Muzaffarnagar white* and *Etawah white* are known. Consequently, a number of landraces from the region, with resistance to Karnal bunt, leaf blight, heat tolerance, and several other desirable features, particularly resistance to biotic and abiotic stresses have been identified at the Directorate of Wheat Research, Karnal (Singh *et al.,* 2006c). In barley, genetic variability for saline and alkaline conditions prevailing in UP has been collected (Verma *et al.,* 2006), and varieties such as C84 (K84), a selection from Aligarh local, C50 (K50) from Sithapur local, and Type 4 from Rewari local have been developed. In maize, *Teenpakhya* is known from UP, and landraces such as *Sathi* (that matures in 65–70 days in summer) have been identified with high tolerance to heat (Saxena *et al.,* 1994). In pearl millet, wide variation has been observed in plant height, flowering time, shape and size of spike and grain (Rao *et al.,* 1983).

Among grain legumes, in pigeonpea, significant variability has been observed, and landraces such as ICP 7626 with resistance to wilt have been collected and used in the development of the variety Maruti (Remanandan and Singh, 1997). Another variety T7 was developed from a sample collected from Lucknow (Singh *et al.,* 2006a). In lentil and pea, a wide range of diversity has been observed in seed size, shape, color, and time to maturity in material collected from Haryana and UP regions along the Yamuna river (Singh *et al.,* 2006b), leading to the development of varieties such as Pant L234 from P230. In cluster bean, the region offers variability for early maturity, determinate habit, disease resistance, and fodder yield. In moth bean, Type 1 has been developed from a landrace collected from Meerut with spreading habit, medium bold seed, and late maturity (Dabas *et al.,* 2006). There is variability in cowpea regarding its habit, flower color, coloration of plants including pod and seed, and their size.

Among oilseeds, the region has recorded significant variability in *Brassica rapa*, with early and dwarf types, particularly in cultivars of varieties *Toria* and *Yellow sarson*. Consequent of this, several varieties have been developed from local landraces, for example in *B. rapa* var. *toria,* T-9, a selection from 5509 of UP, T-36 from a local landrace of Etawah, TL-15 from Karnal local, and Bhiwani, a selection from a local landrace collected from the *Terai* region of UP. In *B. rapa* var. *yellow sarson*, T-10 a selection from Kanpur local, T-151 from Aligarh local, K-88 from Etawah local, Ragini (MYSL 203) from Allahabad local, and YST151 from Barabanki local have been produced (Kumar *et al.*, 2004). In *B. juncea*, T-11 from a landrace of Kanpur, Shekhar (KR5610) from Etawah local, Narendra Rai from Atwa local, Kanti (RK9807) from Kanpur local, and Laha

101 (T101) from landraces of Etawah, Pusa Kisan (T6342) from a landrace of Agra have been developed. In *Eruca sativa,* T-17 has been developed from Gurgaon local (Kumar *et al.,* 2004). In safflower, the variability has been recorded in the form of a wild relative, *Carthamus oxycantha*, growing as a weed in the region.

The Indo-Gangetic Plains appear to be the center of origin and diversity for *Gossypium arboreum*. All races of *G. arboreum* are derived from the northern perennial *arboreum* cotton (Singh *et al.,* 2004). The region is also known for the significant genetic variability in *Saccharum spontaneum,* a wild relative of sugarcane, distributed in the sub-Himalayan region from Dehradun to the Sunderbans, offering variability in desirable features such as resistance to diseases, insect pests, drought, salinity, and waterlogging.

The region is an important center of genetic diversity for vegetable crops, because it offers diverse agroecological niches for adaptation. In brinjal (*Solanum melongena*), landraces such as *Ramnagar Baingan* (long fruit type is suitable for the Ganga River belt), *Dudhiya Baingan* (cluster bearing fruit type), *Jethuwa Baingan* (suited for summer plantation), Haryana Brinjal 14, *Kuchabuchia Baingan* (small cluster bearing type), *Jafrabadi* (deep purple, round oval type with less seeds), and *Balfahwa Jathuwa Bhanta* (tall, perfuse branching, cluster bearing, better shelf life type, suited to summer cropping) offer desirable variability. Similarly, in chili, there is significant variability in fruit shape, size, and color (Kalloo *et al.,* 2005).

In cucurbits, the region is an important center of diversity for *Cucumis melo* and *Citrullus lanatus*. The round gourd *Praecitrullus fistulosus,* a monotypic genus that is nearly endemic to the region, was domesticated here and so did the ash gourd *Benincasa hispida,* adding important sources of food. The region has downy mildew and root rot wilt complex resistant types in *Praecitrullus fistulosus*. The andromonoecious type in *Lageneria siceraria* from Faizabad and Shahjahanpur are important from the breeding point of view. In several of these crops, varieties have been developed through selection from local landraces: for example, in muskmelon, Lucknow safeda from Lucknow local; in *Cucumis sativus*, Kalyanpur green from a local cultivar; in smooth gourd (*Luffa cylindrica*), Kalyanpur Hari Chikni; in ridge gourd (*L. acutangula*), Punjab sadabahar; in *Momordica charantia*, Kalyanpur Barahmasi and Pusa Videsh from Hapur local; and in *C. melo* var. *utilissimus*, Arka Sheetal from Lucknow local (Sirohi *et al.,* 2005). In addition, several wild species of these crops, such as *Luffa echinata*, *Cucumis satosus, Momoridica balsamina,* etc. offer further variability for use in the breeding programs.

In potato, the Farakhabad region offers great variability; Agra-red has been derived from a local type (Shekhawat *et al.,* 2005). In okra, Mishra *et al.*(2000) have reported wild species of *Abelmoschus* from the *Terai* belt. Other species reported from the region are *Abelmoschus cancellatus* (Saharanpur), *A. manihot* (Behata and Mahoba), *A. manihot* ssp. *tetraphyllus* (Rampur, Nagina, and Dhampur), and *A. tuberculatus* (Sharanpur). In onion, Pusa Madhawi was developed

from Muzaffarnagar local and Kalyanpur red round from Kanpur local (Pandey *et al.,* 2005). Variability has been recorded in some important spices, such as coriander and fennel, and varieties such as Pant Haritima and Azad Dhania, and Azad Saunf 1, have been developed through selection and mass selection from local landraces respectively.

The region represents rich genetic diversity in the case of tropical and arid fruits. The region has a number of traditional varieties in mango, such as *Bombay green*, *Dashehari*, *Fazli*, *Langra*, *Safeda Lucknow*, *Smarbehisht*, *Chausa*, etc. In guava, a wide range of variability occurs in Allahabad, Mirzapur, Kanpur, Unnao, and Fatehpur, and several traditional varieties, such as *Lucknow 49*, *Allahabad Safed*, *Red flashed* and *Chitidar*, *Banarasi*, *Harijha*, etc., are commonly known for their distinct features (Mitra and Bose, 1999). In arid fruits such as *Aegle marmelos*, local cultivars *Darogaji*, *Ojha*, *Rampuri*, *Azamal*, *Khamaria*, *Kagzi Gonda*, and *Kagzi Etawah* offer a great deal of variability. In *aonla* or Indian gooseberry (*Emblica officinalis*), grown extensively in the region, wide variability for fruit characteristics has been recorded in local landraces such as *Hathijhool*, *Basanti red*, *Deshi*, *Chakaiya*, resulting in the selection and release of many varieties from the Acharya Narendra Dev University of Agriculture and Technology. In *Zizyphus mauritiana*, several forms are available in Western UP and Haryana, and varieties such as Gola Gurgaon, Sanaur 1, Safed Rohtak have been developed. In *jamun* or Java plum (*Syzygium cumini*), the region has a major concentration of variability for fruit size, shape, pulp color, acidity, and earliness, though no pure line has been established yet. Similarly, variability has been recorded in *Grewia subinaequalis* (*phalsa*) (Vashishtha *et al.,* 2005). In lemon (*Citrus lemon*), variability has resulted in the selection of varieties such as Baramasia, Pant lemon, and Gandhraj (Karihaloo *et al.,* 2005).

A number of traditional mixed cropping, intercropping, and crop rotation systems have evolved to suit different agroclimate requirements. The region is also known for several cultural practices for pests and disease control using natural products such as neem cake/leaves/powder and spread of cow-dung ash to control powdery mildew disease, etc. Additionally, the people of the region can be credited with the development of a unique by-product from the local vegetable species: the city of Agra is geographically associated with the sweet called *Petha* made from the ash gourd.

Future perspectives

The region has deep loamy soil having optimum soil–air–water relationship. However, it is the most populous region in the world, putting a great pressure on the natural resources that have been on the decline. The biodiversity of the region is under threat, as reflected by the number of

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species under threat and needs efforts for conservation of species diversity. Similarly, the genetic diversity has been threatened in important crops with the popularization of high-yielding varieties (90% and 60% respectively, in wheat and rice) and with the replacement of traditional cropping systems (millets, pulses, such as chickpea). Can a strategy like the preservation of heritage sites and/or peasant farming systems be an answer to genetic erosion?

Rapid expansion in agriculture and scarcity of water has made access to water as the central issue for the livelihoods of the rural poor and the principal driver for the development of the region. Therefore, effective management of water resources in the region needs immediate attention with steps towards integrated water management and land use, in order to ensure the future sustainability of all production and ecosystems.

Soil fertility decline in the region (Punjab, Haryana) is well recorded and there is a need to study the soil-related problems in the region to a greater depth. It would require greater research on cropping systems and integration of traditional systems (which were more amenable to sustainable or conservation agriculture) with modern farming systems, to evolve new systems, facilitating both conservation and functions of crop growth and production. In this regard, diversification from the rice–wheat system towards high-value agriculture, involving pulses and oilseeds on one side, and horticulture crops such as fruits and vegetables on the other, offers immense opportunities. It may be extended to other lines of high-value agriculture, such as horticulture, livestock rearing, fisheries, etc. If the above steps are integrated with appropriate warehousing, communications, transportation, and cold storage facilities, and are further augmented with modern technological interventions such as adoption of greenhouse farming in horticultural crops, and extension to dairy (Punjab, Haryana), meat, eggs, and fish, the region would become one of the world's highest producer not only in field crops, but also of quality vegetables, fruits, and flowers.

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Full-length paper

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Potential of Some Methods Described in Vrikshayurvedas in Crop Yield Increase and Disease Management

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Abstract

Knowledge of plant protection generated by our ancient and medieval scholars has become available during the last two decades. A good deal of that knowledge, the author believes, is applicable to the crop production in modern India, especially at the small farmers level. It is necessary, however, to validate effectivity of several ancient practices. This paper attempts to suggest the potential of some of those old practices in managing plant diseases. It is hoped that plant pathology researchers will take interest and conduct experiments to check validity of the suggested practices.

In the recent past, whereas the Sanskrit term "Vrikshayurveda" (the science of plant life) was known to a few scholars, most agricultural graduates, including me, had never heard the name during our college education. This situation continued until the Asian Agri-History Foundation (AAHF), Secunderabad, India began its activities in 1994.

There is only one ancient copy on palm leaves of Surapala's Vrikshayurveda (c.1000 AD) in the world preserved at the Bodleian Library, Oxford University, UK. The author obtained a microfiche in 1994 from the Bodleian Library. A printout was then obtained using the microfiche. A Bulletin with Sanskrit text, its English translation, and commentaries by scientists was published in 1996 by AAHF. In the last 15 years, the term "Vrikshayurveda" has become widely known amongst agriculturists not only in India but also in other countries.

In fact the term "Vrikshayurveda" has been in use since ancient times. By the time Kautilya (296–321 BC) compiled his "Arthasastra", the term "Vrikshayurveda" was well-established and well-known. The next document on Vrikshayurveda, a very brief one, was compiled as "Brhat Samhita" by Varahamihira (505–581 AD).

We then find two texts compiled in the 11th century AD; Surapala's Vrikshayurveda (c. 1000) and Vrikshayurveda chapter in Lokopakara composed by Chavundaraya (1025). In the 12th century AD, Chalukya King, Someshvardeva compiled an encyclopedia "Abhilashitarthachitamani" or "Manasollasa" in which a full chapter on Vrikshayurveda was included. We then find a 13th-century AD text titled