*Allelopathy Journal* 7 (1) 1-55 (2000)

0971-4693/94 US $ 5.00


# *Juglans* spp., juglone and allelopathy

R.J. WILLIS

School of Botany, University of Melbourne, Parkville, Victoria 3052, Australia

**(Received in revised form : February 26, 1999)**

**CONTENTS**



**Keywords :** Allelopathy, crops, history, *Juglans* spp., juglone, phytoplankton, walnut, soil, trees

## 1. INTRODUCTION

The "walnuts" are referable to *Juglans*, a genus of 20-25 species with a natural distribution across the Northern Hemisphere and extending into South America. *Juglans* is a member of the family Juglandaceae which contains 6 or 7 additional genera including *Carya, Cryptocarya* and a total of about 60 species. Walnuts are commercially important as the source of the edible walnut, the highly prized timber and as a specimen trees. Eating walnuts are usually obtained from *J. regia* (the common or Persian walnut, erroneously known as the English walnut) - a native of SE Europe and Asia, which has long been cultivated, but are also sometimes available locally from other species such as *J. nigra* (back walnut) - a native of eastern North America and *J. major, J. californica* and *J. hindsii,* native to the western U.S.

Grafting of superior fruit-bearing scions of *J. regia* onto rootstocks of hardier species, such as *J. hindsii* or *J. nigra* is common practice. The species of walnuts are in need of revision, particularly those from South and Central America, and from East Asia, as more than 60 species have been recognised in the past. At present about 20-25 species and numerous varieties are recognised; the better known species are listed in Table 1.

Table 1. Major species of *Juglans* (compiled from various sources)

| Species | Common name | Distribution |
|---|---|---|
| **Europe/Asia** | | |
| *J. regia* L. | Common or Persian walnut | S.E .Europe, Asia; widely planted |
| *J. mandshurica* Maxim. | Manchurian walnut | N.E. Asia |
| *J. ailanthifolia* Carrière | Japanese walnut | Japan, Russia |
| *J. cathayensis* Dode | | China |
| North America/South America | | |
| *J. nigra* L. | Black walnut | E.US; widely planted |
| *J. cinerea* L. | Butternut or white walnut | E.US and Canada |
| *J. major* (Torr.) Heller | Arizona walnut | S.W.US, Mexico |
| *J. microcarpa* Berl. | Little walnut or Texas black walnut | S.W.US |
| *J. hindsii* (Jepson) Jepson | Claro or N.California walnut | California |
| *J. californica* S. Wats. | California walnut | California |
| *J. olanchana* Standl. & Williams | Central American walnut | Mexico, Central America |
| *J. mollis* Engelm. ex Hemsl. | | Mexico, Guatemala |
| *J. pyriformis* Liebman | | Mexico |
| *J. jamaicensis* C. DC | Nogal or West Indies walnut | West Indies |
| *J. australis* Griseb. | Argentina, Bolivia | |
| *J. neotropica* Diels | Ecuador, Colombia | |
| **Hybrids** | | |

*J. intermedia = J. nigra* x *J. regia*

*J. quadrangulata = J. cinerea* x *J. regia*

Since antiquity, the walnut tree is known as a source of substances harmful to other living things. For example, rotting fruits were used by native North Americans to stun fish and decoctions of leaves have long been used by fishermen to drive worms to the soil surface. Many American folk uses for walnut, including foliage as a repellent for ants and flies, have been described (313). Such was the baneful reputation of the walnut in parts of Italy, that it is called "witches' tree" (302). However, walnut also provides amongst the earliest recorded suggestions of allelopathy and to this day walnut provides the best paradigm of allelopathy, which has attracted much attention from the popular press (34, 63, 95, 215, 251) and community service programs (99, 126, 138,. 139).

## 2. HISTORICAL BACKGROUND

Early writings about the walnut concern the Old World species *Juglans regia*, the common or Persian walnut. The earliest recorded statement regarding the harmful effects of the walnut trees came from the Roman author Varro (309), writing in about 36 B.C.: "*If, for instance, he* [your neighbour] *has an oak-grove on the common boundary, you would be wrong to plant olive trees on the edge of such a wood, for these trees have a natural antipathy to it so great that, not only do they bear worse, but even, in their efforts to escape, bend away inwards toward the farm precisely as does the vine if planted near cabbage. Like oak trees, walnut trees near your farm, if of large size and standing at little distance from one another, make its margins totally unproductive.*" Pliny (224) further expanded on this: "[The shade] *of the walnut is heavy and even causes headache in man*] *and injury to anything planted in its vicinity.*" and "*To each kind of plant shade is either a nurse or else a step-mother - at all events for the shadow of a walnut tree or a stone pine or a spruce or a silver fir to touch any plant whatever is undoubtedly poison.*" He also notes that: "*The oak and the olive are parted by such inveterate hatred that if one be planted in the hole from which the other has been dug out, they die, the oak indeed also dying if planted near the walnut.*"

These notions were commonly reiterated and sometimes augmented in subsequent natural history and agricultural tracts in the Medieval period. Of particular interest is the Andalusian region which had a rich history of agricultural writers beginning with Columella. The Arab world had a number of great libraries as the Arabs, unlike the Europeans, had access to paper; however, the vast majority of the books were burnt during the Christian purges of the 15th and 16th centuries. Arabic science, mainly under the influence of Jabir ibn Hayyam, developed a complex system of antipathies and sympathies, based largely on supposed compositions of things from the elements of water, air, earth and fire (161). The few surviving agricultural writings from this era seem to have a more practical basis. The writings of the 12th century Andalusian writer Ibn Al-Awwam were largely based on a number of predecessors but these works, notably that of the 10th century Persian, Ibn Wahshiyya have printed been recently. *al-Filaha al Nabatiyya* or Nabathean Agriculture, compiled by Ibn Wahshiyya, may owe its origins to ancient Babylonian writings and, thus, predate Greek and Roman writings, but the earliest known version in Arabic dates to the 8th century. Ibn Wahshiyya (137) states numerous plant sympathies and antipathies but these commonly retain an occult influence. In describing the walnut he says that it is "*the opposite of the pomegranate with respect to cold and heat. It is mostly hot.*" In the context of the era, the references to "heat" likely relate to the bitterness (juglone), as later it is stated: "*it is rare for the walnut to be attacked by diseases because the tree is strong, hard and hot and thus can protect itself from disease and weakness.*" and "*It is harmful because the heat of its fruit is intense and the heat causes pimples and black marks.*" Ibn Al-Awwam's work, while important in his era, was effectively lost until the 19th century when translations appeared in Spanish (135) and French (136), although it was evidently known to the 16th century writer, Herrera (129). Ibn Al-Awwam wrote of the walnut (translated from 136): "*All trees planted in the vicinity demonstrate antipathy, with the exception of the fig, which is found to have several points of agreeability.*"

Hadj of Grenada says "*That the walnut is antipathetic to most trees that one wishes to plant in its vicinity, except the fig and the mulberry, because the walnut is of excessive scorching and dryness, which is harmful to all which come near it and which are not sympathetic to it. It destroys everything which grows beneath it, except certain winter plants, or ferny plants, which one can grow beneath its branches when it is bare of its leaves; when one wants to associate with climbing grapevines, they do not succeed at all and fail at the utter limit of enfeeblement.*"

The 13th century writer Albertus Magnus (2) described the walnut as unfavourable to surrounding cultivated plants because of *its "indwelling extreme toxic bitterness*". Pietro di Crescenzi in his work *Agricoltura Commodorum* (62), written in 1304 and printed in 1471, stated that walnuts were harmful to surrounding trees. Cardano (48) attributed the harmful effects of walnut to the shade-assisted accumulation of "*vapours*".

The writings of Pliny and other Latin authors were compiled and augmented with information from Ibn Al-Awwam and other Hispano-Arabic writers by Herrera (129). He records that the Castilian name for walnut has the meaning of "to harm", although it is now generally regarded that Romance language names for walnut such as *nogal* (Spanish), *noyer* (French) and *noce* (Italian) are derived from the Latin *nux* for nut. This etymological misconception is paralleled in English, with the term "noxious" derived from the Latin *noxa*, meaning harm. Curiously, Fuchs (94) in 1550 claimed that the unrelated Greek word for walnut *karyon* was also derived from a word meaning causing headache.

The first indication of controversy concerning the harmful effects of walnut appears in 1664 in the writings of Evelyn (86). Evelyn was a great proponent of planting walnut in England and he described how, in Burgundy, where walnut is planted in wheat fields by farmers, "*It is so far from hurting the crop, that they look on them as a great preserver, by keeping the ground warm.*" However, farmers in Burgundy avoid planting grapes beneath walnut (183).

A significant advance on walnut toxicity appears in the writings of Worlidge (330) in 1677, as he provides a statement of the mechanism of injury, some two hundred years prior to the often quoted statements of Stickney and Hoy (281). Worlidge writes: "*There is a sympathy and antipathy in plants. And many fabulous traditions there are concerning them, but this is certainly observed that some trees will not thrive under the shade or drip of another, as the drip of a walnut tree and of a cherry are injurious to other trees, because the leaf is bitter and the drip destroyeth such trees or plants that are under it.*"

Well indicative of knowledge of the walnut in Europe in the seventeeth century, and the way in which Pliny's information was augmented, is the account of Estienne (85), who regards the French term for walnut as also meaning "harmful": "*The walnut is a species common enough in all parts, & known to bear such a name [noyer] because it is noxious to others which are neighbouring, in the places where it is planted, & and to people & even to babies, all the more one sees by experience, that if a man sleeps below, he will wake up with great heaviness of the head and so stunned that he nearly cannot move himself. And its shade is so bad that nothing good can grow underneath there, & that also the roots are of marvellous extent, which spoils all the land where this tree is situated & planted. Thus it should not be planted in a workable field, and especially in those which are richest and most fertile, rather towards the North, on the side of roads or elsewhere, where there are no other fruits which can receive damage from this tree. To place a tree of another species among them, it is not any more useful than putting a little artisan among two great lords; for walnut trees which are naturally great miners with their large roots, remove its food even in a trench, & the cover from its above blocks the sun, & the liberty of the air also: but because the things of this world are thus composed, there is not anything that would not have some adversaries, one must not house the walnut, even plant, or transplant near the oak, not even place it in a trench where an oak has been planted before, because these two trees have a natural hatred for each other, & cannot grow together.*"

By the close of the 18th century new information began to be added. For example, in Phillips' *Pomarium Britannicum* (220), in addition to mention of Pliny, it is stated that a well known London strawberry-grower, Mr. Keen, has noted that "*the walnut is so injurious to strawberry beds, that they seldom bear fruit in the neighbourhood of that tree.*" The harmful effect of the walnut was common knowledge in Europe and for example, appears in de Stendahl's novel of 1831, *Le Rouge et le Noir*: "*Each of these cursed walnuts, said M. de Rénal when his wife admired them, costs me the harvest of a demi-arpent, wheat cannot grow under its shade.*" According to Crozier (64), the secretary of the Central Horticultural Society of France wrote: "*Shrubs and underwood will generally thrive and flourish when planted under beech trees, but will not even live when planted under the shade of the walnut.*"

During the latter half of the 19th century it became apparent that American species, most notably the black walnut (*J. nigra*), also were injurious to other plants. This seems to be first recorded in the *Transactions of the Illinois State Horticultural Society*. Firstly, Galusha (101), in discussing that "*certain kinds of trees are poison to an orchard*", recorded that his neighbour, in planting a row of black walnut trees on one side of his apple orchard, found after 12 years that almost all the adjacent apple trees had died. In 1874, there was a lively discussion at the Illinois State Horticultural Society (193) and Mr. McWhorter and Mr. Douglas agreed that black walnut affected the palatability of grass for stock. Mr. Bryant added that he had witnessed black walnut killing apple trees within a radius of about 25 meters and he thought that walnut roots were in some way poisonous. However, others at the meeting were in disagreement and, when Dr. Schroeder commented that walnut leaves "*contain a great proportion of bitter stuff and they embitter the ground and make it sick*", he was confronted with laughter.

Remarkably similar comments appear elsewhere in the American agricultural press. A Pennsylvanian farmer, Mr. O. Snowberger, wrote to a Farmers' Club in New York (7): "*I feel satisfied that I have seen three apple trees destroyed by black walnuts and I believe they destroy grape vines. I judge it is the water dropping from the walnut leaves that does the work.*". In a discussion before the Wisconsin State Horticultural Society in 1881, Stickney and Hoy (281) concluded that "*the main reason why vegetation does not thrive under these trees* [black walnut] *is the poisonous character of the drip.*"

In 1883, an American report similar to that by Galusha (101) was published in an English forestry Journal (8): "*Some thirty years ago I planted an orchard of about 200 apple trees on one of my farms - open prairie. Having a lot of three to four -year old Walnut trees growing from seed, I planted a few rows of them on the north side as a windbreak. Both did well for some time, and now some of the walnut trees have reached a height of 40 feet. The first row of Apple trees has long since been* *killed out. The rest of the orchard is doing well; having a large crop of fruit during the past season and is generally fruitful. With my experience, I should as soon think of feeding poison to my stock as planting such trees near enough to Apple trees to subject the latter to their influence. My grove of Walnut trees is much admired by passers-by. This would seem to deprive arboricultural schemes of the romance with which they have been surrounded in theory."*

However, despite the apparent widespread experience of the so-called "walnut toxicity", Crozier (64) dismissed all such claims as unsupported.

## 3. THE EFFECTS OF WALNUTS ON OTHER PLANTS

### 3.1 *Juglans nigra*

#### 3.1.1 Effects on crop plants

**I.Grape vine :** In the early twentieth century, Hedrick (125) stated that grape vines were harmed by walnut trees. The injurious effects of walnut were known to Schreiner and Reed (264, 265) at the USDA Bureau of Soils, but were not investigated by them.

**II. Tomato :** The unfolding of the walnut story really begins in the 1920s, as both the symptomatology and chemistry of walnut toxicity were elucidated at the Virginia Agricultural Experiment Station. Cook (61), in a brief note, described the wilting of tomato plants as affected by *Juglans nigra*. Massey (185, 186) collated many observations of his colleagues on the effects of black walnut on tomato. The results from a spraying experiment were particularly striking (186): a set of small square plots of tomato plants happened to be bordered by two black walnut trees, all tomato plants within 15 m and 12 m respectively, of the two trees were injured. Massey noted that, in a large alfalfa field which contained a solitary black walnut tree, alfalfa was generally absent and replaced by grass within the vicinity of the tree and that the damage seemed root-related. Massey observed that black walnut injured tomato plants and potato plants, to a lesser extent, but not beets, snap beans or corn in his home garden. He subsequently set up three simple experiments. He established that walnut root bark added to water culture would cause wilting and browning of roots of tomato within 48 h, that root bark added to soil would also cause poor growth, but that walnut soil alone caused no effect. Massey concluded that there must be some toxic principle which may be initially insoluble in water , or may alter chemically once it leaves the root. He surmised that the chemical was likely the hydroquinone juglone.

**III. Apple :** Schneiderhan (258, 259, 260) reported the demise of apple trees which were near black walnut trees, apparently a commonly known problem in Virginia. He added that only *J. nigra* and *J. cinerea* appeared injurious, as *J. hindsii* and *J.*

*californica* supported intercrops; he also regarded *J. regia* as not injurious. In the course of a cursory survey in Frederick County, Virginia, Schneiderhan found eighteen instances of walnut injury to apple trees. The average distance of 48 dead apple trees was about 11.9 m from a walnut tree and the average distance of 14 injured apple trees was about 14.3 m. Schneiderhan speculated that the relatively common occurrence of walnut toxicity in Frederick County may be related to the shallow soil and consequent intermingling roots. He also speculated that among the local apple varieties, Stayman may be more resistant to walnut toxicity. Schneiderhan's observations were confirmed by the experiences of Smith (272) whose walnut trees were on various grafted stock. Smith also found that alfalfa suffered on his property. Difficulties with black walnut were also reported from West Virginia (210, 211).

In 1928 Davis, working at the Virginia Agricultural Experiment Station isolated juglone from both hulls and roots of black walnut (70). Juglone was administered to both tomato and potato plants by injection into the stem, causing severe effects. Both natural and synthetically prepared juglone caused similar effects. The apparent identification of the cause of walnut toxicity was considered sufficiently important to warrant mention in the *New York Times* (11) and to gain service as a sermonic metaphor (204).

The various reports on walnut toxicity which appeared in the 1920's caused some degree of panic in certain quarters, as farmers who had not experienced any problems with walnut trees immediately felt threatened. Miller (195) attempted to rebut Schneiderhan's comments in describing an old apple orchard containing walnut, in which injured or dead tress were not near walnut trees. An editorial in the *Washington Star* (9) ridiculed the idea that the walnut tree was toxic and in alarmist manner, attempted to blame any scientist [Schneiderhan] for any loss of walnut trees due to their felling. Others (28) compared the effect of walnut simply to that of any other large tree exerting a strong competitive effect. The confirmation of juglone in walnut toxicity then generated a vigorous controversy which was staged over several years largely at the annual meetings of the Northern Nut Growers Association. Scepticism about walnut toxicity was led by Greene (110, 111) who cited a number of reports by farmers claiming that plants grew admirably under their walnut trees. Hershey (130) was outraged at some of the discussions at the 1929 meeting of the Northern Nut Growers Association and responded with a facetious note blaming any plant injury on "intangible poisons" and there was a move to suppress negative information about black walnut (12).

During the 1930s and 1940s there were continued, largely anecdotal, reports concerning the effects of black walnut on other crops (175, 191, 223, 237, 238, 262, 271, 272 , 284, 323) but often the information was contradictory. MacDaniels, who had a long association with the Northern Nut Growers Association, was evidently spurred by the Association (69) and reported on some pot experiments in which tomato and alfalfa plants were planted in walnut soil but there appeared little evidence of inhibition (175). Walnut hulls placed around a grape vine seemed only to enhance growth. Tomato plants planted close to a black walnut tree showed little adverse effect until late in the season. This work was continued by Brown (43), who showed that alfalfa and tomato in contact with walnut root bark were retarded in germination and strongly inhibited in seedling growth. Tomato seedlings grown in nutrient solutions with added walnut root bark were significantly inhibited even when given full nutrients but, particularly, when nitrogen deficient. There was evidently conflict among walnut growers over the issue of walnut toxicity, particularly as California growers with plantations of *J. regia* on their own roots or on grafted stock could not offer any evidence supporting a toxic effects (175), and, in 1948, the USDA (300) attempted to defuse the situation through the extraordinary means of a press release reassuring the public of the harmless nature of walnut trees, in particular, to tomato.

Curiously, the first detailed experimental work on the effects of black walnut on tomato was conducted in Germany, by Bode (32; 279, 280). When tomato seedlings were grown in the nutrient solution supporting two year-old walnut seedlings, Bode could find no evidence of injury, concluding that root excretion of juglone was not a significant factor. This is not surprising in view of the limited solubility of juglone in water, but Bode was also unaware that juglone production may become more significant with maturation of the tree. He found that juglone reached the soil through leaf leachate, leaf litter and also through the litter created by male catkins.

The interaction which has attracted the most detailed study is the pronounced effect of walnut on tomato. Originally, this was described by Massey (185) and Brooks (42) as a wilting phenomenon. Bode (32) observed marked epinasty of the leaves, premature yellowing of the leaves, shortened internodal growth and decreased lateral root formation. MacDaniels and Pinnow (176) reviewed knowledge concerning walnut toxicity and confirmed that black walnut caused damage to both tomato and peony plants, primarily through root contact. MacDaniels (172) detailed the symptomatology of tomato plants grown near black walnut. The first sign was wilting, sometimes in a single branch and especially during daytime. Some affected plants eventually produced new growth from the base. Examination of the stem tissue revealed discoloured zones, browning of the vascular tissue and the presence of xylem tyloses, which may explain the wilting. In almost all cases of wilted tomato plants, MacDaniels was able to find one or more walnut roots in contact with the tomato root ball. Further work (177) attempted to assess walnut damage to other Solanaceae plants, potato and capsicum (pepper). Potato plants did wilt, but to a much lesser extent than tomato and no tyloses were found; the capsicum plants showed no obvious effects.

Tomato plants are unusually sensitive to juglone; 10 ppm juglone can cause 50% reduction of seedling growth, whereas 100 ppm juglone is lethal (314). The interaction of walnut with tomato plants was also investigated by DePalma (74, 75), who used one-year old seedlings of *J. nigra* in glasshouse and field trials; however, the only inhibition recorded was when walnut root extract was applied to tomato plants and in field experiments, the tomato plants commonly showed enhanced growth when adjacent to walnut plants.

It has been reported that walnut may affect the taste of beets but not affect yield (221). The interaction of *J. nigra* with crops such as corn and bean planted in alley cropping systems has been demonstrated in trenching experiments (146, 147). While competition, particularly for water, is of prime importance in such systems, it appears that minimising the contact of crop roots with juglone is also significant. Kipkech (155) found that leaf vegetables varied in sensitivity to being alleycropped with *J. nigra*: the order of sensitivity was Swiss chard (*Beta vulgaris*) > kale (*Brassica oleracea*) > lettuce (*Lactuca sativa*) > parsley (*Petroselinum crispum*). Nutrients such as nitrogen, phosphorus and potassium were generally higher in plantation soil, evidently due to increased inputs of organic matter by walnut but, perhaps, compensated by diminished growth due to inhibition by walnut.

### 3.1.2. Effects on co-planted trees

Black walnut may establish poorly on sites which lack tree cover (49). The use of "nurse species", which either protect the young walnut trees from mechanical damage or, more importantly, enhance the soil conditions, has been recommended to accelerate and improve walnut growth (6, 46, 56, 73, 93, 98, 106, 213, 254, 305, 307). Much of this pioneering work was done at Forestry Science Laboratory, USDA North Central Experiment Station, Carbondale southern Illinois.

Nurse species may also decrease the growth of competing or allelopathic undergrowth species such as the *Festuca* grass (120, 243, 247, 306), notably *F. arundinacea*, itself an allelopathic species and reduce the incidence of walnut diseases such as *Microsphaerella* leaf spot and anthracnose (152, 153). Common nurse species are *Pinus* spp., *Robinia pseudoacacia*, *Eleagnus umbellata* and *Alnus glutinosa*. While pines are generally sensitive to juglone it may take ten years or so before the effects of juglone are apparent and, by this time, walnut trees are well established (6). The use of legumes such as black locust (*Robinia pseudoacacia*) has proved problematic as its rapid growth overtopped coplanted walnuts; lespedeza failed altogether (56). Riëtveld (245) tested the effects of juglone ($10^{-3}$ M to $10^{-6}$ M) on 14 herbs and shrubs potentially useful as covercrops or nurse species and found that all were sensitive to juglone. Germination and radicle extension were generally less affected than shoot elongation and dry weight accumulation. The species most affected in bioassay were *Lonicera maackii, Lespedeza cuneata, Trifolium incarnatum, Alnus glutinosa* and *Eleagnus umbellata*. However, Ponder *et al.* (226) found that soil from walnut plantations, with and without *Alnus glutinosus* or *Elaeagnus umbellata*, had no significant effect on the growth or *Rhizobium* nodulation of the covercrop *Vicia villosa,* although inhibition could be demonstrated through application of juglone in sand culture.

*Eleagnus umbellata* and *Alnus glutinosa* are actinorrhizal and are capable of increasing soil nitrogen through the action of the actinomycete *Frankia*. However, it was found that nurse species may prosper for a period of 8-13 years, after which the increased root system of walnut and/or the apparent accumulation of juglone in the soil causes the decline of the nurse trees (246). Contrary to the findings above (245), juglone is reported to have little direct effect on *Alnus* growth but affects nodulation and the activity of *Frankia*. Curiously, of five *Frankia* isolates tested, the one associated with *Alnus crispa*, a species relatively rich in the phenolic pinosylvin, was the most resistant to juglone (311, 312). It was found that the growth of *Frankia in vitro* was reduced exponentially as juglone concentration increased from $10^{-6}$ M to $10^{-3}$ M (71). At a concentration of $10^{-4}$ M juglone had a severe effect on the growth, *in vitro*, of the nitrogen fixing symbionts *Frankia* and *Rhizobium* and concentrations as low as $10^{-6}$ M caused significant inhibition in *Rhizobium*, although Rhizobium was slightly more tolerant at juglone concentratrion of $10^{-4}$ M (72). In further experiments (205, 206), seedlings of *Alnus glutinosa* were grown hydroponically and it was found that juglone at concentrations of $2 \times 10^{-5}$ and $2 \times 10^{-6}$ M inhibited nitrogenase activity after one day and after five days, respectively. Juglone at $2 \times 10^{-5}$ M caused reduced root respiration and plant growth. However, juglone added to soil only had an effect at a concentration of $10^{-3}$ M and this effect ceased after 22 days evidently due to detoxification by the soil. Contrary to the results of Fisher (89), the authors found that a wet soil regime did not increase the longevity of the juglone in the soil. Work by Heckman and Kluchinski (121) suggested that leaf litter of *J. nigra* did not contribute significantly to inhibition of nodulation or nitrogen fixation in legumes. Ponder and Tadros (227) examined the role of juglone in a 14-year old walnut plantation containing the nurse species *Alnus glutinosus* and *Eleagnus umbellatus* on an upland site in southern Illinois. They found that juglone levels, which were significantly greater in walnut-black alder plantings than in pure walnut or walnut-autumn olive plantings, could be the cause of the relatively early demise of black alder trees in walnut plantations. Ponder (225) also examined the interaction of black walnut with *Alnus glutinosa* and *Eleagnus umbellata* in a 15-year old bottomland plantation in southern Illinois and, similarly, found that lower concentrations of juglone in topsoil were associated with plantations coplanted with *E. umbellata*, likely due to enhanced microbial degradation. Ponder also reported that there were differences in the soil nitrifiers in different plantings. However, these differences were not directly correlated with juglone, but were likely caused through changes to the understorey vegetation.

Understanding the dynamics of juglone can be important in walnut plantation management, particularly where the trees are harvested for timber. The harvesting process can result in the release of substantial quantities of juglone in debris and through damaged roots (58). If it is desirable to maintain intercropped species, it may be preferable to harvest later in the year when juglone levels are low or, if replanted walnut seedlings require a competitive edge, then harvesting in summer may be advantageous. Often, the allelopathic effects of walnut are unforeseen; for example, Gabriel (100) describes how an arboretum for white birches (series Excelsae) was established on a site which was partly occupied by 12 surviving trees from a failed black walnut plantation. Within one year 15 out of 200 various white birches had died and of these, 13 were near a black walnut. Dead birches were replaced with new birch plantings and after 4 years, 11 of the 13 troubled walnut sites again caused birch mortality and a further 8 birches had succumbed near walnut trees, whereas there were only 4 other losses away from the walnuts.

The negative effect of black walnut on conifers planted nearby is well known and supported by numerous observations, where it has commonly been found that conifer plantations, especially those of *Pinus* spp., established next to walnut trees show high mortality near the common border (5, 42, 45, 87, 118, 218, 244, 262, 263, 321). Research with juglone has demonstrated that seedling growth of *Pinus strobus* can be inhibited by as little as 10-7 M juglone (51). Seedlings of *Pinus strobus* grown for 8-10 weeks in hydroponic culture were injured by 10-6 M juglone; *Larix leptolepis* *Picea abies* and *Pinus sylvestris* by 10-5 M juglone; 10-4 M juglone killed *Larix leptolepis* and *Pinus sylvestris* and 10-3 M juglone killed all four species (97). Fisher (89) demonstrated that the allelopathic effect of black walnut on *Pinus resinosa* and *Pinus strobus* was linked with poor soil drainage and assumedly longer retention of juglone in the soil. Van Sambeek (303) concluded that walnut was a superior competitor on better sites and under competition stress, probably produced more juglone which affected pine; however, on deep well drained sites, co-existence was possible as juglone may not build up in the soil.

### 3.1.3. Effects on natural vegetation

Although *Juglans* spp. are considered to be amongst the best equipped plants to affect other plants via allelopathy, there are surprisingly few data on the effects of walnut on surrounding vegetation under natural conditions. However, it was not until 1951 that Brooks (42) attempted to document the effects of walnut on surrounding vegetation in a broad context, although most of the trees studied were in an agricultural setting. In view of these well known effects, Conrad (59) investigated the effect of leaf and hull extracts of black walnut on the germination and seedling growth of eight deciduous trees including black walnut itself, but found no significant effects.

The effects of fresh leaf and hull extracts on the early germination stages of *Liquidambar styraciflua*, *Platanus occidentalis* and *Robinia pseudoacacia* were examined more closely, but any inhibitory effect proved temporary. Bratton (38) examined the effects of *J. nigra* on old field succession and found that it was inhibitory to *Ulmus americana* and *Fraxinus pennsylvanica*. De Scisciolo *et al.* (77) compared the understorey vegetation in several planted mixed hardwood stands containing *J. nigra*, *Acer saccharum* and *Quercus rubra* and could detect no qualitative differences. The density of understorey vegetation was actually significantly higher under *J. nigra*. The only significant interactions recorded were positive associations with *Rubus occidentalis*, *Circaea quadrisulcata* and *Dryopteris spinulosa* and an unexpected negative interaction with *A. saccharum* seedlings. Recently, Talley *et al.* (288) found that the root-climbing liane *Rhus radicans* is less abundant than expected on *J. nigra* and that bark extract can inhibit the germination of *R. radicans*. The absence of the herb dittany (*Cunila origanoides*) under certain hardwood species led van Sambeek *et al.* (304) to investigate the effect of root, foliage and decaying leaves leachates of several species, including *J. nigra*; however, the authors could not find any significant effect attributable to allelopathy.

## 3.2. *Juglans regia*

### 3.2.1. Effects on other plants

The Persian walnut *Juglans regia* is widely grown throughout the world as an ornamental or crop tree. Its inhibitory effect on understory vegetation is supposedly "well known" (169), but has been little studied in comparison to black walnut. Molisch (197) found that volatiles from Persian walnut shoots were slightly inhibitory. However, most information regarding the Persian walnut seems anecdotal. During the early years of the black walnut controversy, California walnut growers noted poor growth of plants under *J. regia* but found that this could be remedied through nitrogen application (175). Generally, it is acceded by American growers agreed that *J. regia* is less toxic than *J. nigra*, although results (222) illustrate that the relative degree of inhibition of the two species in bioassay depends on the test species. It has been noted that potatoes, beans and alfalfa do not grow well beneath walnut (162). In northern India, *J. regia* is commonly grown along bunds and terrace risers of cultivated fields and there is low species richness underneath the canopy in comparison to control areas (24, 25). Furthermore, of eight trees studied, *J. regia* was found to have the most pronounced effect in reducing winter crop biomass (by 69%) and an even more pronounced effect on summer crops. Leaf leachates of *J. regia* were found to inhibit germination of several agricultural species (194) and leaf extracts of *J. regia* were inhibitory to seedling growth of wheat and corn and to germination of corn, but not wheat (294). Walnut has also been implicated in "soil sickness" problems, that is, the re-establishment or maintenance of a walnut plantation may prove difficult for no obvious reason (92). While organic compounds have been identified in contributing to "soil sickness" problems of fruit species such as apple and peach, there are no such data about walnut, as yet, and it may be that temporary depletion of soil nitrogen by understory vegetation is the major cause.

Grümmer (114), in his important monograph on allelopathy, remarked that in its native habitat in Asia Minor, walnut woodland has a rather poor understorey which may be linked in some way to juglone, but he offered no evidence. In recent times, this view has been confirmed by Hussain *et al.* (134) who further reported that, in Pakistan crops such as corn, turnip, potato and beans were commonly unthrifty when grown near walnut trees. The authors subsequently found that extracts of walnut leaves, stems, hulls and bark, litter leachate and rain leachate inhibited the germination and seedling growth of corn, turnip and bean. Shoot extracts of *J. regia* were found to completely inhibit the germination of winter weeds such as *Alopecurus myosuroides*, *Lactuca sativa* and *Raphanus raphanistrum*, while the grass *Lolium multiflorum* was not significantly affected (301). With summer herbs, *Amaranthus retroflexus*, *Digitaria sanguinalis*, *Portulaca oleracea* were significantly inhibited, while *Prosopis stephaniana* and *Xanthium strumaria* were not. In view of the potential effects of juglone, Bauckmann (22)sluited four different mixtures of grasses under walnut trees, and found no effects of suppression.

Kolesnichenko (158) noted that oak was inhibited by walnut. Leaf leachates, root extracts and soil extracts of *J. regia* have all been shown to demonstrate some degree of inhibition in bioassay (23, 159, 249), but little else is given. Tyzh *et al.* (299) grew walnut seedlings in excavated walnut soil and found no injurious effects, which is not surprising in view of the lability of juglone in soil as reported with *J. nigra*.

### 3.2.2. Effects on phytoplankton

It has been suggested that walnuts may affect freshwater biota through runoff and/or the leaching of walnut litter in water; this may be a particular problem in areas supporting walnut processing where washings are feared to harm fish (232). While the effects of juglone on aquatic animals are well known, its effects on phytoplankton are comparatively little known. Juglone was found to affect *Spirogyra* and *Chilomonas* at concentrations as low as $10^{-7}$ M (102), and studie with *Euglena* showed that photosynthetic forms were far more senstive than colourless forms (261). Krajci and Lynch (160) surveyed the inhibitory effects of walnut hull extracts and juglone on a number of microorganisms including the cyanobacteria *Calothrix*, *Anabaena* and *Anacystis* and the green algae *Bracteacoccus* and *Coelastrum*. However, concentrations of juglone were in excess of 30 ppm. Randall and Bragg (234) found that the cyanobacterium *Nostoc commune* and the desmid *Scenedesmus* were inhibited by 1 ppm juglone and the cyanobacteria *Anabaena flos-aquae* by 0.5 ppm juglone, whereas *Chlorella pyrenoidosa* was unaffected even by 10 ppm juglone. At very low concentrations (10 ppb, 100 ppb), juglone had a slight stimulatory effect on *Nostoc*, *Anabaena* and *Scenedesmus*. Kessler (150, 151) found that the green algae *Closterium*, *Micrasterias*, *Pandorina*, *Eudorina* and *Spirogyra* were even less sensitive to juglone as these species were either unaffected or showed slight stimulation at 1.74 ppm ($10^{-5}$ M) juglone. He, thus, concluded that the most likely effect of walnut leachate on freshwater algae was increased biomass because of inhibition of herbivores more sensitive to juglone.

### 3.3. Other walnuts spp.

**I. *J.cineraria:*** *J.cinerea*, another native of eastern North America, is known as the butternut, or less commonly as the white walnut. It is of little commercial value and is seldom planted, hence, it has not attracted attention similar to *J. nigra* and *J. regia*. Jones and Morse (145) reported early observations made by A.H. Gilbert that cinquefoil (*Potentilla fruticosa*), a common weed was generally found dead within a circular area often greater than the canopy of butternut (*Juglans cinerea*) trees and that injury seem related to intermingling of cinquefoil roots with butternut roots. The extent of the effect generally increased with the age of the tree. It has also been observed that *J. cinerea* was associated with the death of *Pinus mugo* (272). The only experimental work with *J. cinerea* showed no significant effects on tomato plants (74, 75), although the plants of *J. cinerea* were only a year old.

**II. *J.major* :** The Arizona walnut, *J. major*, is also regarded as an allelopathic candidate and *J. mandshurica* has been found to be inhibitory in bioassay (192).

The lack of convincing results demonstrating allelopathy with *J. nigra* or *J. regia* in a natural setting is not surprising and is similar to the situation found with *Eucalyptus*, another genus with a good chemical armoury (327, 328). The results summarised, above, conform with the theories of Rabotnov (230, 231), who suggested that allelopathy is unlikely to be obvious in natural environments where selection over millions of years has already filtered those species intolerant of the toxins concerned. Conversely, allelopathy is likely to be most dramatic in environments, especially those artificially created such as in agriculture, where species with little coevolutionary history are brought together.

## 4. JUGLONE

The allelopathic effects of the walnuts have been usually ascribed to the compound known as juglone, although this approach is likely overly simplistic. Indeed, there is a variety of other secondary metabolites in *Juglans*, which have been implicated in allelochemical interactions, including phenolic acids (41, 117, 134).

flavonoids (184, 277), amines (168), alkaloids (30), terpenes (19, 169) and of course, naphthalenyl derivatives. Juglone (5-hydroxy-1,4-naphthoquinone or 5-hydroxy-1,4-naphthalenedione) is one of the naphthoquinones, which occur infrequently and usually in small amounts in plants; however, juglone is an oddity in that occurs in relative abundance. It is of great interest to ecologists as it has been implicated in a wide array of allelochemical interactions, including allelopathy. Its generally ready availability, its relative ease of isolation or preparation and its predictable performance in bioassay have made it a common subject in allelopathic work, for example, in classroom experiments (143, 198, 274, 285, 322), theoretical and methodological studies in allelopathy (82, 269, 315, 317) and bioassay studies of the comparative toxicity of various organic compounds (242). Juglone has also been the subject of numerous postgraduate dissertations in the plant sciences (33, 35, 74, 76, 88, 150, 166, 238, 239, 268, 314). Juglone was first isolated in 1856, but named juglone in 1877 and became primarily of interest as a dyestuff (320). Juglone is an orangeish compound which sublimes at 155°C. It can be noticed when fresh bark is stripped from walnut roots or fresh fruit hulls are cut, as the tissue turns yellowish due to the formation of juglone. There is some dispute over the natural occurrence of juglone: Daugherty *et al.* (68) maintain that juglone is restricted to the Juglandaceae, although they only tested the Juglandaceae and closely related families. Juglone occurred in all seven species of *Juglans* examined and in some species of related genera such as *Carya, Platycarya, Pterocarya, Cyclocarya.* However, there are also reports of juglone occurring in genera of unrelated families: *Lomatia* (Proteaceae) (196), *Caesalpinia* (Caesalpiniaceae) (203) and *Astragalus* (Fabaceae) (179). It has also been reported as a metabolite of various fungi: *Penicillium diversum* var. *aureum* (96), a mutant form of *Verticillium dahliae* (283) and *Mycosphaerella fijiensis* (282).

Research by Dow Chemical Co. has, apparently, suggested that UV radiation is required for the biosynthesis of juglone, which may explain why some experiments with *J. nigra* in glasshouses, where most of the UV radiation was lost, yielded negative results (174). However, in direct conflict with this is a statement by Cline and Neely (57), who maintained that juglone concentrations are higher in glasshouse seedlings than in field grown specimens. Recent work by Renesse (238) indicates leaf extracts of *J. nigra* and *J. regia* become much more inhibitory after exposure to O2 and full light, which suggests that photocatalysis is involved. Juglone can be biosynthesised through an apparent nexus of pathways which originate with *o*-succinylbenzoic acid (199), derived from the shikimic acid pathway (see Figure 1). Juglone is most abundant in the plant as a glycoside of α-hydrojuglone (1,4,5-trihydroxynaphthalene) which, following enzymatic hydrolysis to release the sugar, is readily oxidised to juglone under aerobic conditions. Juglone or its precursors may participate in the formation of more complex compounds including methylated forms (27); several juglone oligomers, including dimers, trimers and possibly, tetramers have been identified in tissues from *Juglans* spp., but their function is unknown (122, 131, 212).

The fact that freshly cut walnut hulls will turn firstly yellow with juglone and then turn black, after further oxidation, indicates that other compounds can be easily formed from juglone (113). The fate of juglone in the environment has recently been elucidated (see Figure 1) and degradation proceeds enzymatically via the action of the bacteria *Pseudomonas putida* J1 or J2 which, ultimately, forms 2-hydroxymuconate semialdehyde and pyruvate (202, 240, 241).

At one point juglone itself was thought not to occur naturally in plant tissue but was thought to be present only in the form of a glycoside of 1,4,5-trihydroxynaphthalene (α-hydrojuglone). It is now accepted that juglone, in addition to its precursors and by-products, can be found in plant tissues, although most often in small quantities. However, in some structures, such as in fruits of *J. regia*, there can be a distinct gradient of juglone and its concentration is greatest in the epicuticular wax, where its concentration has been recorded as constituting up to 29.8% of the wax (228). Similarly, Binder *et al.* (27) found that juglone and 5-hydroxy -4-oxo-α-tetralone or 2,3-dihydro-5-hydroxy-1,4-naphthalenedione (β-hydrojuglone) comprised 18.6% (18.2 ppm) and 3.3% (3.2 ppm) of the naphthoquinone compounds of peelings of unripe black walnut (*J. nigra*) fruits whereas, for the whole hull, these quantities changed to 26% and 56%, respectively. It is not known whether juglone concentration changes with the age of the tree; experiments with walnut seedlings have often shown little allelopathic activity (e.g. 304). However, even cotyledons of germinated walnut seeds contain the β-glucosidase required to convert hydrojuglone-β-glucopyranoside to the aglycone α-hydrojugone which, under aerobic conditions, rapidly oxidises to the more stable juglone (83).

Pedersen (214) has shown that electron spin resonance spectroscopy is a rapid and simple technique for assaying juglone/hydrojuglone from small plant samples: he found that, in eight species of *Juglans* screened, the leaf concentrations were 1.4-2.9 mg/g DW basis, although the technique which detects *ortho*- and *para*-quinols, thus, measures 'total juglone'. Recently, Girzu *et al.* (105) have provided a method for the specific determination of juglone from fresh samples, using high-performance liquid chromatography. Girdling experiments suggest that juglone is produced in the leaves or other green tissues and then translocated via the phloem (37). Prataviera *et al.* (229) found that the xylary sap of *J. regia* contained juglone and could cause grafting failure. The juglone concentration in the xylem sap of *J. regia* has been found sufficient to inhibit seedling growth in bioassay (229, 291).

**4.1.Pests management**

The raison d'être for juglone, like most similar secondary metabolites, is linked primarily to defence against a range of enemies including insects, nematodes, bacteria and fungi. Juglone is well established as a deterrent to insects (104, 108, 116, 144, 208, 235, 295, 318) and insects which feed on members of the Juglandaceae commonly are less affected by juglone (295). As is often the case in the course of coevolution, a few insects which feed selectively on *Juglans* have exploited the toxicity of juglone: for example, the larvae of the chrysomelid beetle *Gastrolina depressa* secrete juglone to deter ant predators (189). The ready availability of juglone has attracted some interest in exploiting its properties as an insecticide (31, 250).

Juglone has been shown to play a role in disease resistance in scab caused by *Cladosporium caryigenum* (37, 80, 329), walnut blight caused by *Xanthomonas campestris* (52) and anthracnose caused by *Gnomonia leptostyla* (57), galls caused by *Phylloxera* spp. (124) and *Fusicladium effusum* (123). Juglone has been employed as a successful treatment against some fungal plant pathogens (275). It appears to offer the first line of defence against invasion as it is, for example, an effective inhibitor of conidia germination in *C. caryigenum* but has no effect on subsequent colony growth or sporulation (329). This accords with the unusually high concentration of juglone in the cuticle. There is considerable seasonal variation in juglone quantities in differing tissues and juglone is usually most abundant during the younger stages of the plant structure. For example, Borazjani *et al.* (37) reported that juglone attains its highest level in leaves in June and in nuts in September. Juglone also appears to act as a phytoalexin and is commonly found to be more abundant in damaged or infected tissues (80, 115, 124), although Hedin *et al.* (122) found that the amount of 'total juglone', including its precursors, does not increase in damaged tissues of pecan. Juglone has also been found to increase the activity of polypholoxidase *in vitro* (29) and, thus, may also play an ancillary role in defense. The presence of juglone in root tissue may be linked to its nematodicidal effects (91, 178). An enigmatic feature of *Juglans* spp. is that, despite the presence of juglone, most species appear to be capable of forming mycorrhizae, both endotrophic and ectotrophic (e.g. 49, 266), which suggests that the fungal associates have mechanisms capable of detoxifying or sequestering juglone. Marked intraspecific variation to vasicular-arbuscular colonisation within seedlings of *J. nigra* (81) support this view.

### 4.2. Germination and seeding growth

As juglone is a naphthoquinone it is very reactive in biological systems, which probably explains why it generally is not recorded in large amounts in healthy plant tissue. There are numerous studies which have demonstrated that juglone can inhibit germination and seedling or plant growth (88, 133, 267, 324) or accelerate senescence (53), including one which has attempted to assess the effect of substitution type and position within the naphthoquinones (276). Among the few commonly occurring naphthoquinones, plumbagin (2-methoxy-5-hydroxy-naphthoquinone), followed by juglone, are the most inhibitory. Generally, juglone can act readily in oxidation/ reduction reactions and, as a reductant, may concomitantly create potentially harmful free radicals such as superoxide and hydroxide (267). Juglone can be used as an artificial electron acceptor in the Hill reaction (249, 289); it is a useful tool in cell biology generally as an electron acceptor and as an inhibitor of numerous cell processes, especially those which rely on the movement of cations such as K+ or Ca++ across membranes (90, 207, 308). Juglone has been found to disrupt the activities of mitochondria and chloroplasts. These effects and other may be due to its reaction with thiol groups (127, 128, ,157, 170, 209, 216, 217, 219). Juglone appears to have the ability to interfere with the synthesis (S) phase of the cell division cycle which may be due, again, to its reactivity with thiol groups and may have potential as an anti-cancer drug (148). Juglone can affect basic plant processes such as cell division, cell elongation and root formation (60, 156), and it behaves as a typical plant growth substance in bioassay in having a greater effect on radicle growth than on hypocotyl growth (293). Its similarity to synthetic plant hormones, such as naphthalene acetic acid, suggests that it may act as a plant hormone under certain circumstances ( 1, 32, 60). More recently, juglone has been shown to promote root formation in walnut seedlings (140, 141).

## 5. VARIABILITY IN THE EFFECT OF WALNUT

Probably the most vexing issue regarding allelopathy in walnut is the variability of the effect. This occurs for several reasons: (a) marked differences in the abundance of juglone and associated naphthoquinones among and within the different walnut species, (b) distinct seasonal differences in the occurrence of naphthoquinones in walnut species, (c) distinct differences in the susceptibility of plant species to walnut allelopathy and (d) geographical differences in allelopathic effect of walnut due largely to light conditions, soil conditions and soil microbiology.

### 5.1. Interspecific and intraspecific variation

Juglone is regarded as a constituent of most, if not all, of the known walnut species, and has been confirmed (either as juglone or hydojuglone) in *Juglans nigra, J. regia, J. cinerea, J. mandshurica, J. major, J. ailantifolia, J. x intermedia* var. *vilmoreana, J. stenocarpa, J.rupestris, J. cathayensis* as well as some species of the related Juglandaceae genera *Carya, Pterocarya*, etc. (68, 103, 214). Among *Juglans* spp. it is generally considered that the highest juglone concentrations are found in *J. nigra* and that this species has been observed to cause the most damage to other plant species. However, Matveev (192) in bioassays with *J. mandshurica, J. nigra* and *J. regia* found that aqueous foliar of extracts of *J. mandshurica* were most inhibitory. It is worth noting that levels of juglone have been found in *Pterocarya* spp. comparable to those in *Juglans* spp. (214). Thus, this genus also warrants study as an allelopathic candidate.

While there has been considerable work on the seasonal variability of juglone in walnut (see below), but, little work has been done on intraspecific variation. It has been realised that in the nut-growing industry this facet has great importance in breeding programs as juglone levels, particularly in pecan, have been linked to resistance against various pathogens. Although it is evident that the effect of walnut on other vegetation can be quite variable (42, 244) the causes can be manifold. Among the few data on intraspecific variation in juglone in walnut, Lee and Campbell (167) found that the *J. nigra* cultivar 'Ohio' had significantly greater concentration of juglone in the hulls than did the cultivar 'Thomas' and an unnamed seedling, but the same cultivar had the lowest juglone levels in its foliage. Cline and Neely (57) reported unusually high juglone levels (11.2 mg/g leaf DW) in one particular tree amongst their samples. De Scisciolo *et al.* (77) found up to ten-fold variation of juglone concentrations in soil under several different walnut trees; however, while these occurred on different soils, there appeared no correlation with any soil parameter. Renesse (238) found that three different varieties of *J. regia* differed markedly in their performance in various bioassays. There may or may not be variation in juglone concentration within a single tree; Lee and Campbell (167) found no difference in jugone concentrations from samples collected from the upper and lower parts of a tree, whereas Coder (58) recorded significantly higher juglone levels in the lower parts of the leaf crown, possibly due to differences in photosynthesis or light-induced decay of metabolites.

Another little studied aspect of juglone variation in walnut relates to the age of the tree. It is commonly reported that toxicity problems, for example, with nurse crop species, are not apparent for several years and then there is a relatively rapid decline of the nurse trees. This situation may be related to a genuine physiological difference between young and adult walnut trees (32, 74, 75, 221), or is more likely an expression of a juglone threshold in soil being reached due to an increasing root system and juglone load. In one study (167), a two-year old black walnut seedling was found to have a juglone concentration of 7.73 ppm (DW basis) in its roots in September, which was six times the concentration found in the foliage.

### 5.2. Seasonal variation

Most investigators have found that the abundance of juglone in the species known to contain high levels of juglone, such as *J. nigra*, conform to the plant apparency theory; that, is allelochemicals occur in tissues during the periods when they are most vulnerable to herbivores and/or pathogens. This occurs, typically, during leaf opening and during fruit formation and is reflected in reported high levels of juglone in leaves in June/July and high levels in fruits in August -September. However, the months showing maxima can vary among cultivars (167). The overall situation is further complicated, as different investigators have measured the abundance of different compounds under the rubric of "juglone". As juglone is toxic, it is usually stored as the more benign α-hydrojuglone glycoside. Thus, some investigators seeking pure juglone in walnut tissue may obtain low values (e.g. 32, 66) while other investigators have chosen to measure juglone 'potential' or 'total juglone' through successive extraction in an oxidising environment, which means that juglone precursors, such as α-hydroquinone, form juglone during the extraction process. For example, Borazjani *et al.* (36) found that juglone levels in *J. nigra* leaves averaged about 1.3 mg/g (fresh weight) during the growing season and peaked in June, which accords with the data of other workers (109, 122, 123). Whilst Coder (58) used the same methodology as the preceding workers, his data appear to be in error, as he reported leaf concentrations of potential juglone of about 0.1 mg/g (dry weight), which was about a hundred-fold difference. The link between juglone concentration and development of the structure is emphasised by results from Hedin *et al.* (123) who found that immature *J. nigra* leaves formed in the late growing season (September) had 1.15 mg/g (FW) compared to 0.045 mg/g in the more common older senescing leaves. Data from *J. regia* shoots show also a build-up of juglone during the growing season with a peak, firstly, in May and then again in July (292, 331).

As discussed previously, juglone is convertible with the hydrojuglones and capable of forming glycosides. Thus, part of the problem in assessing the abundance of juglone in walnut tissue is in determining what exact methods have been used for juglone extraction and measurement. A comparison of two reports from the same group illustrates the discrepancies in the literature: Carnat *et al.* (50) extracted dried leaves of *J. regia* and found no juglone, while Girzu *et al.* (105) extracted fresh (May) leaves of *J. regia* and recorded specifically juglone, using spectrometry, levels of about 0.5% (fresh weight basis), which would convert to about 5% (dry weight basis).

### 5.3. Variation in the effect of *Juglans nigra* on other plants

At first, concern about black walnut centred on its effects on apple, grapes, tomatoes, potatoes and alfalfa but, once the problem became linked to the chemical substance juglone, there became fear in some quarters that black walnut was a "poison tree" and may have to be eradicated from the landscape. In 1951, Brooks (32) finally tackled the problem of which plants were and were not affected by black walnut as, over the course of 12 years, he had surveyed the effects of some 300 mature trees on neighbouring vegetation in five different States. His data are somewhat difficult to interpret as he provides only simple frequencies of some 60 tree species, 35 shrubs and vines and 123 herbaceous species within and without the root spread of black walnut but Brooks does describe those species which he judges to be tolerant or intolerant of black walnut.

There have been numerous reports of the effects of black walnut and/or juglone on individual species but there have been no serious attempts to document the effect of black walnut on vegetation patterning. Effects somtimes defy common sense; toxicity may be more apparent several meters from the trunk, even outside the canopy, because the roots nearest the tree are too deep to make contact with other roots (221). Clearly, there is wide variation in the response of plant species to walnut but there can also be intraspecific variation in tolerance of walnut compounds such as juglone (245). In recent years, a considerable volume of information has become available through agencies such as the American Horticultural Society, university extension services and nurseries; much of this has been disseminated in leaflet form and/or in electronic form via the Internet. While most of this information is unsubstantiated, much of it has been generated by experienced or professional growers. The various lists of plants recorded in this century as being affected or unaffected by black walnut are collated in Table 2. Reports sometimes contradict one another, for example, as in the case of persimmon and holly, perhaps because of intraspecific variation in the walnut trees observed, different cultivars used or, more likely, soil differences. Furthermore, assessment of sensitivity may vary because of differing methodology; a plant such as *Lonicera maackii* is very sensitive to juglone in bioassay or hydroponic culture (244) but may grow satisfactorily under field conditions. There are some groups such as the conifers (Pinophyta), Betulaceae, Ericaceae, Oleaceae, Rosaceae and Solanaceae, where there is a high percentage of plants reported as affected by black walnut. In most of these groups there is at least one member which appears to be resistant and, commonly, it is a species whose natural range coincides with that of *Juglans* spp. and/or *Carya* spp. For example, the confiers *Juniperus virginianus*, *Pinus virginiana* and *Tsuga canadensis*; *Rhododendron periclymenoides* in the Ericaceae; *Forsythia* spp. in the Oleaceae; *Crataegus* spp., *Cydonia oblonga*, *Malus coronaria*, *Prunus serotine* and *Rubus occidentalis* in the Rosaceae; and *Physalis* spp. in the Solanaceae, further lends support to the arguments of Rabotnov (230, 231) mentioned previously. At the specific level, it seems also that there are cultivars that are unusually resistant to the effects of black walnut.

Table 2. Species which are reported as affected or unaffected by Juglans nigra

| Division/Family/Sp | Common name | Affected | Unaffected |
|---|---|---|---|
| **EQUISETOPHYTA** | | | |
| *Equisetum arvense* | Horsetail | | 16 |
| **PTEROPHYTA** | | | |
| *Asplenium platyneuron* | Ebony spleenwort | | 16 |
| *Athyrium* spp. | | | 84, 221 |
| *Athyrium asplenioides* | Lowland lady-fern | | 16 |
| *Athyrium thelypteroides* | Silvery spleenwort | | 16 |
| *Botrychium dissectum* | Dissection grape fern | | 16 |
| *B. dissectum var. obliquum* | Common grape fern | | 16 |
| *Bulbinopsis bulbosa* | | | 221 |
| *Dennstaedtia punctiloba* | Hay-scented fern | | 16 |
| *Dryopteris cristata* | Crested wood fern | | 14, 15, 251 |
| *Dryopteris intermedia* | Intermediate shield fern | | 16 |
| *Dryopteris marginalis* | Marginal shield fern | | 16, 95 |
| *Dryopteris spinulosa* | | | 77 |
| *Matteuccia struthiopteris* | Ostrich fern | | 15, 84, 221 |
| *Onoclea sensibilis* | Senstive fern | | 14, 16, 84 |
| *Osmunda cinnamomea* | Cinnamon fern | | 14, 15, 16, 95 |
| *Polystichum* spp. | | | 15, 221 |
| *Polystichum acrostichoides* | Christmas fern | | 15, 84, 95 |
| *Woodsia obtusa* | Obtuse Woodsia | | 16 |
| **LYCOPODOPHYTA** | | | |
| *Lycopodium complanatum* var. *flabelliforme* | | | 16 |
| **PINOPHYTA** | | | |
| *Juniperus chinensis* | | | 17 |
| *Juniperus virginiana* | Red cedar | | 16, 17, 34, 67, 84, 176, 221, 270 |
| *Larix kaempferi* | Japanese larch | 16 | |
| *Picea abies* | Norway spruce | 16, 67 | 17 |
| *Pinus densiflora* | Japanese red pine | 261 | |
| *Pinus jefferyi* | Jeffrey pine | | 16, 17 |
| *Pinus mugo* | Swiss mountain pine | 16 | |
| *Pinus nigra* | Austrian pine | 261 | |
| *Pinus resinosa* | Red pine | 5, 16, 34, 67, 89, 176, 221, 270 | |
| *Pinus rigida* | Pitch pine | 16 | |
| *Pinus strobus* | White pine | 16, 67, 89, 218, 221, 244 | |
| *Pinus sylvestris* | Scotch pine | 16, 67, 244 | |
| *Pinus taeda* | Loblolly pine | 16, 67 | |
| *Pinus thundbergi* | Japanese black pine | 261 | |
| *Pinus virginiana* | Scrub pine | | 16 |
| *Thuja occidentalis* | Arborvitae | 16 | 16, 17 |

| | | | |
|---|---|---|---|
| *Tsuga canadensis* | Canadian hemlock | | 14, 16, 17, 67, 84, 251 |
| **MAGNOLIOPHYTA** | | | |
| **LILOPSIDA** | | | |
| **AMARYLLIDACEAE** | | | |
| *Galanthus nivalis* | Glory-of-the-snow | | 14, 15, 84, 95, 251 |
| *Narcissus* spp. | Daffodil | | 67 |
| *Narcissus* 'John Evelyn', 'Unsurpassable', 'King Alfred', Ice Follies' *et al.* | Daffodil | 16 | |
| *Narcissus* 'Cheerfulness', 'Yellow Cheerfulness, 'Geranium', Tete-a-tete', 'Sundial', February Gold' | Narcissus | | 246, 176, 221 |
| **ARACEAE** | | | |
| *Arisaema triphyllum* | Jack-in-the-pulpit | | 15, 16, 67, 84, 95, 221 |
| *Asarum europaeum* | Wild ginger | | 14, 15, 16, 84, 251 |
| **COMMELINACEAE** | | | |
| *Commelina communis* | Virgina day flower | | 16 |
| *Tradescantia virginiana* | Spiderwort | | 14, 15, 84, 251 |
| **CYPERACEAE** | | | |
| *Carex* spp. Sedges | 16 | | |
| **DIOSCOREACEAE** | | | |
| *Dioscorea villosa* | Wild yam | | 16 |
| **IRIDACEAE** | | | |
| *Crocus* spp. | Crocus | | 14, 15, 16, 84, 95, 251 |
| *Iris* spp. | Iris | | 16, 221 |
| *Iris siberica* | | | 14, 15, 84, 95 |
| **LILIACEAE** | | | |
| *Allium cepa* | Onion | | 16, 67, 176, 221, 283 |
| *Asparagus officinalis* | Asparagus | 16, 270, 283 | |
| *Chionodoxa lucilliae* | Glory-of-the-snow | | 15, 84, 251 |
| *Colchicum* sp. | Autumn crocus | 67, 176, 221 | |
| *Convallaria majalis* | Lily-of-the-valley | 223 | |
| *Erythronium* spp. | Dog-tooth violet | | 15, 84, 95, 221 |
| *Hemerocallis* spp. | Daylily | | 15, 16, 67, 84, 95, 251 |
| *Hemerocallis fulva* | Daylily | | 14 |
| *Hosta* spp. | Plantain lily | 223 | 15, 84, 95, 221 |
| *Hosta fortunei* | Plantain lily | | 14, 251 |
| *Hosta lancifolia* | Plantain lily | | 14, 251 |
| *Hosta marginata* | Plantain lily | | 14 |
| *Hosta undulata* | Plantain lily | | 14 |

| | | | |
|---|---|---|---|
| *Hyacinthoides* spp. | Spanish bluebell | | 251 |
| *Hyacinthoides hispanicus* | Spanish bluebell | | 14, 15, 84 |
| *Hyacinthus* x | Hyacinth | | 14 |
| *Hyacinthus* 'City of Haarlem' | Hyacinth | | 84 |
| *Hyacinthus orientalis* | Hyacinth | | 15, 251 |
| *Lilium* cvs | Lily | | 221 |
| *Lilium* 'Enchantment', Asian hybrids | Lily | 16 | |
| *Liriope* spp. | | | 16, 67 |
| *Muscari botryoides* | Grape hyacinth | | 14, 15, 16, 84, 95, 251 |
| *Ophiopogon* spp | Mondo grass | | 84, 221 |
| *Polygonatum* spp. | Solomon's seal | | 84 |
| *Polygonatum commutatum* | Solomon's seal | | 14, 15, 221, 251 |
| *Scilla siberica* | Siberian squill | | 15, 16, 84, 251 |
| *Tricyrtis hirta* | Toad lily | | 15, 84, 221 |
| *Trillium* spp. | Trillium | | 15, 16, 67, 221 |
| *Trillium cernuum* | Nodding trillium | | 14, 84, 251 |
| *Trillium grandiflorum* | White wake-robin | | 14, 84, 251 |
| *Tulipa sp.* | Tulip | | 283 |
| *Tulipa greigii* 'Toronto' | Tulip | | 84, 95 |
| *Tulipa* x Darwin 'White Volcano', Cum Laude' | Tulip | | 14, 84, 95, 251 |
| *Tulipa* x 'Merry Widow', 'West Point | Tulip | 16 | |
| *Tulipa* x 'Blue Parrot' | Parrot tulip | | 84 |
| *Uvularia* spp. | | 221 | |
| *Uvularia grandiflora* | Big merrybells | | 14, 15, 84, 95, 251 |
| *Uvularia perfoliata* | Bellwort | | 16 |
| **ORCHIDACEAE** | | | |
| *Habenaria lacera* | | 16 | |
| *Spiranthes gracilis* | Slender ladies tresses | | 16 |
| **POACEAE** | | | |
| *Agrostis alba* | Redtop | | 16, 34, 67, 174, 221 |
| *Andropogon virginicus* | | 34, 273 | |
| *Arrhenatherum elatius* | Tall oatgrass | | 16, 34 |
| *Avena* sp. | Oat | | 34 |
| *Bromus* sp. | Brome grass | | 16, 34 |
| *Dactylis glomeratus* | Orchardgrass | | 16, 34, 67, 174, 221 |
| *Danthonia spicata* | Poverty grass | 34, 176, 221 | |
| *Festuca elatior* | Fescue | | 34, 67 |
| *Festuca* | Tall fescue | | 270 |
| *Holcus lanatus* | | | 34 |
| *Holcus mollis* 'variegatus' | Velvet grass | | 16 |
| *Lolium* sp. | Rye | | 34 |
| *Muhlenbergia schreberi* | Nimblewill | | 16, 34 |
| *Panicum clandestinum* | Deer tongue grass | | 16, 34 |
| *Phleum pratensa* | Timothy grass | | 16, 34, 67, 176 |
| *Poa compressa* | Canada bluegrass | | 16 |
| *Poa pratensis* | Kentucky bluegrass | | 16, 34, 67, 211, 221, 270 |

| | | | |
|---|---|---|---|
| *Triticum aestivum* | Wheat | | 16, 34, 67 |
| *Zea mays* | Corn | 258 | 16, 34, 176, 221, 270, 283 |
| | | | |
| **SMILACEAE** | | | |
| *Smilacina racemosa* | False spikenard | | 16 |
| *Smilax* spp. | Greenbriar | | 16 |
| **MAGNOLIOPSIDA** | | | |
| **ACERACEAE** | | | |
| *Acer* spp. | Maple | | 221 |
| *Acer ginnala* | Ginnala maple | 244 | |
| *Acer negundo* | Box elder | | 16, 17 |
| *Acer nigrum* | Black maple | | 16, 17 |
| *Acer palmatum* | Japanese maple | | 14, 16, 84, 248, 251 |
| *Acer palmatum 'dissectum'* | Japanese maple | | 16, 248 |
| *Acer rubrum* | Red maple | | 16 |
| *Acer saccharum* | Sugar maple | 77 | |
| *Acer saccharinum* | Silver maple | 16, 67 | |
| | | | |
| **ANACARDIACEAE** | | | |
| *Rhus canadensis* | Fragrant sumac | 16 | |
| *Rhus copalina* | Dwarf sumac | | 16 |
| *Rhus glabra* | Smooth sumac | | 16 |
| *Rhus hirta* | Staghorn sumac | | 16 |
| *Rhus radicans* | Poison ivy | 287 | 16, 34, 221 |
| | | | |
| **ANNONACEAE** | | | |
| *Asimina triloba* | Papaw | | 16, 17 |
| | | | |
| **APIACEAE** | | | |
| *Daucus carota* | Wild carrot | | 16, 34, 270, 283 |
| *Myrrhis alpestris* | Sweet cicley | | 15 |
| *Pastinaca sativa* | Parsnip | | 16, 174, 221, 283 |
| | | | |
| **APOCYNACEAE** | | | |
| *Vinca minor* | Periwinkle | | 15, 221 |
| | | | |
| **AQUIFOLIACEAE** | | | |
| *Ilex opaca* | American holly | 16, 251 | 17 |
| *Ilex verticillata* | Michigan holly | 16 | |
| | | | |
| **ARALIACEAE** | | | |
| *Aralia spinosa* | Hercules club | 16 | |
| | | | |
| **ARISTOLOCHIACEAE** | | | |
| *Aristolochia macrophylla* | Pipe vine | 16 | |
| | | | |
| **ASTERACEAE** | | | |
| *Achillea millefolium* | Common yarrow | | 16, 34, 270 |
| *Ambrosia* spp. | Ragweed | | 16, 34 |
| *Antennaria* spp. | Pussy's toes | | 16 |

| | | | |
|---|---|---|---|
| *Aster* spp. | Aster | | 16, 34, 84, 270 |
| *Bidens* spp. | Beggar-ticks | | 16, 34 |
| *Calendula officinalis* | Pot marigold | | 14, 84, 251 |
| *Chicorium intybus* | Chicory | | 16 |
| *Chrysanthemum* spp. | Shasta daisy | | 16 |
| *Chrysanthemum* spp. | Chrysanthemum | 270, 283 | 14, 15, 248 |
| *Chrysanthemum leucanthemum* | Ox-eye daisy | | 16 |
| *Chrysanthemum morifolium* | Chrysanthemum | 16 | |
| *Cirsium* spp | Thistle | | 16, 34 |
| *Dendranthema* sp. | | 251 | |
| *Doronicum* spp. | Leopard's-bane | | 14, 15, 84, 251 |
| *Elephantopus* spp. | Elephant's foot | | 16 |
| *Erigeron annuus* | Daisy fleabane | | 16, 34 |
| *Erigeron philadelphus* | Philadelphia fleabane | | 16 |
| *Eupatorium coelastinum* | Mist-flower | | 16 |
| *Eupatorium purpureum* | Joe-Pye weed | | 16 |
| *Helenium* spp. | Sneezeweed | | 16 |
| *Helianthus* spp. | Sunflower | | 16 |
| *Helianthus tuberosum* | Jerusalem artichoke | | 14, 15, 251 |
| *Hieracium* spp. | Hawkweed | | 16 |
| *Hieracium auranticum* | Orange hawkweed | | 14, 15, 251 |
| *Lactuca* spp. | Wild lettuce | | 16 |
| *Ligularia* sp. 'Desdemona' | | | 251 |
| *Prenanthes* spp. | Rattlesnake-root | | 16 |
| *Rudbeckia hirta* | Brown-eyed susan | | 16 |
| *Senecio aureus* | Golden ragwort | | 16, 34 |
| *Solidago* spp. | Goldenrod | | 16, 34 |
| *Taraxacum* spp. | Dandelion | | 14, 16, 34, 270 |
| *Vernonia* spp. | Ironweed | | 16, 34 |
| *Zinnia* spp. | Zinnia | | 84, 270, 283 |
| **BALSIMINACEAE** | | | |
| *Impatiens* spp. | Jewelweed | | 16 |
| **BEGONIACEAE** | | | |
| *Begonia* spp. | Begonia | | 14, 84, 270 |
| *Begonia x semperyirens cultorum* | Begonia | | 251 |
| **BERBERIDACEAE** | | | |
| *Berberis canadensis* | American barberry | | 16 |
| *Epimedium* spp. | Epimedium | | 84, 95, 221 |
| *Podophyllum emodi* | Mayapple | | 221 |
| *Podophyllum peltatum* | Mayapple | | 15, 16, 84, 95 |
| **BETULACEAE** | | | |
| *Alnus glutinosa* | European alder | 67, 244 | |
| *Alnus rugosa* | Smooth alder | 16 | |
| *Betula alba* | White birch | 16, 100 | |
| *Betula lenta* | Sweet birch | | 16 |
| *Betula lutea* | Yellow birch | 16 | |
| *Betula nigra* | River birch | 16 | 17 |

| | | | |
|---|---|---|---|
| *Betula nigra* 'Heritage' | River birch | | 16 |
| *Carpinus caroliniana* | American hornbeam | 16 | |
| *Corylus americana* | Hazelnut | | 16 |
| **BIGNONIACEAE** | | | |
| *Catalpa bignonioides* | Common catalpa | | 14, 16, 84, 248, 251 |
| **BORAGINACEAE** | | | |
| *Myosotis* sp. | Forget-me-not | 223 | |
| *Myosotis alpestris* | Forget-me-not | | 15, 221 |
| *Myosotis sylvatica* | Forget-me-not | | 84 |
| *Pulmonaria* spp. | Lungwort | | 14, 16, 84, 251 |
| **BRASSICACEAE** | | | |
| *Brassica* spp. | Mustard | | 16 |
| *Brassica oleracea* var. *botrytis* | Cauliflower | | 283 |
| *Brassica oleracea* var. *capitata* | Cabbage | 16, 67, 84, 270 | 283 |
| *Dentaria* spp. | | | |
| *Hesperis matronalis* | Toothwort | | 16 |
| | | | 251 |
| **BUXACEAE** | | | |
| *Pachysandra* spp. | | 16 | |
| **CAESALPINIACEAE** | | | |
| *Cassia marilandica* | Wild senna | | 16 |
| *Cassia nicitans* | Wild sensitive plant | | 16 |
| **CAMPANULACEAE** | | | |
| *Campanula americana* | Tall bellflower | | 16 |
| *Campanula latifolia* | Bellflower | | 14, 15, 84, 251 |
| **CAPRIFOLIACEAE** | | | |
| *Lonicera* spp. | Honeysuckles | | 221 |
| *Lonicera* sp. | Red-bud honeysuckle | | 283 |
| *Lonicera canadensis* | American fly-honeysuckle | 16 | |
| *Lonicera maackia* | Amur honeysuckle | 244 | 16, 17, 67 |
| *Lonicera tatarica* | Tatarian honeysuckle | | 14, 16, 17, 248, 251, 283 |
| *Lonicera xylosteum* | European fly honeysuckle | | 16, 17 |
| *Sambucus canadensis* | Common elderberry | | 16 |
| *Viburnum* spp. | Viburnum | 221 | 84, 221 |
| *Viburnum acerifolium* | Maple-leaved viburnum | | 16 |
| *Viburnum dentatum* | Arrow-wood | 16 | |
| *Viburnum lantana* | Wayfaring tree viburnum | | 16, 17 |
| *Viburnum opulus* | European cranberry bush viburnum | 16 | |
| *Viburnum plicatum* | Double-file viburnum | 16 | |
| *Viburnum prunifolium* | Black haw | | 16 |
| *Viburnum sieboldii* | Siebold viburnum | 16, 176 | |
| **CARYOPHYLLACEAE** | | | |
| *Cerastium scandens* | Mouse-ear chickweed | | 16 |
| *Dianthus armeria* | Deptford pink | | 16 |
| *Stellaria media* | Chickweed | | 14 |

| | | | |
|---|---|---|---|
| **CELASTRACEAE** | | | |
| *Celastrus scandens* | Climbing bittersweet | | 16 |
| *Euonymus* spp. | | 221 | |
| *Euonymus alatus* | Burning bush | | 176, 221 |
| *Euonymus americanus* | Strawberry bush | 16 | |
| *Euonymus europea* | European spindletree | | 16, 17 |
| *Euonymus hamiltoniana* | Yeddo euonymus | | 16, 17 |
| **CHENOPODIACEAE** | | | |
| *Beta vulgaris* | Sugar beet | 16, 283 | 16, 34, 176, 221, 270, 283 |
| CLUSIACEAE | | | |
| *Hypericum* spp. | St. John's wort | | 16 |
| *Hypericum prolificum* | Shrubby St. John's wort | | 16 |
| **CONVOLVULACEAE** | | | |
| *Convolvulus arvensis* | Field bindweed | | 16 |
| *Ipomoea tricolor* | Morning glory | | 251 |
| *Ipomoea tricolor* 'Heavenly Blue' | Morning glory | | 14, 84 |
| **CORNACEAE** | | | |
| *Cornus alternifolia* | Alternate-leaved dogwood | | 16 |
| *Cornus amomum* | Silky dogwood | 16 | |
| *Cornus florida* | Flowering dogwood | | 16, 17 |
| **CRASSULACEAE** | | | |
| *Sedum acre* | Golden-carpet | | 14, 15, 84, 251 |
| *Sedum spectabile* | Showy stonecrop | | 14, 84, 251 |
| *Sedum ternatum* | Stonecrop | | 16 |
| **CUSCUTACEAE** | | | |
| *Cuscuta* spp. | Dodder | | 16 |
| **EBENACEAE** | | | |
| *Diospyros virginiana* | Persimmon | 16 | 107 |
| **ELAEAGNACEAE** | | | |
| *Elaeagnus angustifolia* | Russian olive | 16, 244 | |
| *Elaeagnus umbellata* | Autumn olive | 244 | 16 |
| **ERICACEAE** | | | |
| *Azalea* spp. | Azalea | 16, 84, 176, 221, 270 | |
| *Gaylussica* spp. | Huckleberry | 16, 34 | |
| *Kalmia latifolia* | Mountain laurel | 16, 34, 84, 176, 221, 223, 270 | |
| *Pieris* spp. | Pieris | 84 | |
| *Rhododendron* spp. | Rhododendron | 16, 84, 176, 221, 270 | |
| *Rhododendron catawbiense* | | 223 | |
| *Rhododendron maximum* | Rhododendron | 223 | |

| | | | |
|---|---|---|---|
| *Rhododendron periclymenoides* | Pinxterbloom | | 14, 84, 248 |
| *Rhododendron* x Exbury hybrid 'Balzac' | Rhododendron | 84, 95, 248, 251 | |
| *Rhododendron* x Knap Hill hybrid 'Gibraltar' | Rhododendron | 84, 95, 248, 251 | |
| *Vaccinium* spp. | Blueberry | 16, 34, 176, 221, 270 | |
| *Vaccinium corymbosum* | Highbush blueberry | 16 | |
| **FABACEAE** | | | |
| *Baptisia australis* | Blue false indigo | 16 | |
| *Caragana arborescens* | Siberian peashrub | 244 | |
| *Cercis canadensis* | Redbud | | 16, 17, 84, 270 |
| *Coronilla varia* | Hairy vetch | 244 | |
| *Desmodium* spp. | Tick trefoil | | 16 |
| *Gleditsia triacanthos* | Honey locust | | 16 |
| *Gleditsia triacanthos f. inermis* | Thornless honey locust | | 17 |
| *Glycine max* | Soybean | | 16, 184 |
| *Lespedeza* spp. | Lespedeza | | 16, 56 |
| *Lespedeza cuneata* | Sericea lespedeza | 244 | |
| *Lespedeza stipulacea* | Korean lespedeza | 244 | |
| *Medicago* spp. | | 34 | |
| *Medicago sativa* | Alfalfa | 16, 67, 176, 211, 221 | |
| *Melilotus* spp. | Sweet clover | | 16 |
| *Phaseolus lunatus* | Lima bean | | 16, 67, 176, 221 |
| *Phaseolus vulgaris* | Wax bean; snap bean | | 16, 67, 176, 221, 283 |
| *Pisum sativum* | Pea | 270 | 283 |
| *Robinia pseudoacacia* | Black locust | | 16 |
| *Trifolium hybridifolium* | Alsike clover | | 16 |
| *Trifolium hybridum* | | 34 | |
| *Trifolium incarnatum* | Crimson clover | 16, 67, 244 | |
| *Trifolium pratense* | Red clover | | 16, 34 |
| *Trifolium repens* | White clover | | 16, 34, 221 |
| *Trifolium* sp. | Hop clover | | 16 |
| *Vicia faba* | Broad bean | | 34, 270 |
| *Vicia villosa* | Hairy vetch | | 225 |
| **FAGACEAE** | | | |
| *Castanea dentata* | Chestnut | 16 | |
| *Castanea mollissima* | Chinese chestnut | 119 | |
| *Fagus grandifolia* | Beech | | 16 |
| *Quercus spp.* | Oak | | 221 |
| *Quercus alba* | White oak | 244 | 16, 17 |
| *Quercus borealis* | Red oak | | 16 |
| *Quercus coccinea* | Scarlet oak | 16 | |
| *Quercus imbricaria* | Shingle oak | | 16, 17 |
| *Quercus rubra* | Northern red oak | | 16, 17 |
| *Quercus stellata* | Post oak | 16 | |
| *Quercus velutina* | | | 16 |
| **FUMARIACEAE** | | | |
| *Dicentra cucullaria* | Dutchman's breeches | | 15 |

| | | | |
|---|---|---|---|
| **GENTIANACEAE** | | | |
| *Gentiana* spp. | Gentian | | 84 |
| *Gentiana asclepiadea* | Gentian | | 221 |
| *Gentiana septemfida* | Gentian | | 15, 221 |
| **GERANIACEAE** | | | |
| *Geranium robertianum* | Herb robert | | 14, 15, 16, 84, 95, 251 |
| *Geranium sanguineum* | Cranesbill | | 14, 15, 16, 84, 251 |
| **HAMMAMELIDACEAE** | | | |
| *Hammamelis virginiana* | Witch-hazel | 16 | |
| *Liquidambar styraciflua* | Sweetgum | | 16, 17 |
| **HIPPOCASTANEACEAE** | | | |
| *Aesculus glabra* | Ohio buckeye | | 16 |
| *Aesculus octandra* | Sweet buckeye | 16 | |
| **HYDROPHYLLACEAE** | | | |
| *Hydrophyllum virginianum* | Virginia waterleaf | | 14, 84, 251 |
| **JUGLANDACEAE** | | | |
| *Carya* sp. | Hickory | | 16, 221 |
| *Juglans cinerea* | White walnut | 16 | |
| *Juglans nigra* | Black walnut | 95 | |
| **LAMIACEAE** | | | |
| *Ajuga reptans* | Bugleweed | 223 | 14, 15, 84, 95, 251 |
| *Coleus* spp. | Coleus | | 270 |
| *Collinsonia canadensis* | Rich-weed | | 16 |
| *Cunila origanoides* | Dittany | | 303 |
| *Glechoma hederacea* | Ground ivy | | 14 |
| *Hedeoma pulegioides* | Pennyroyal | | 16 |
| *Leonurus cardiaca* | Motherwort | | 16 |
| *Mentha piperita* | Peppermint | | 16, 270 |
| *Monarda* spp. | Beebalm | | 84 |
| *Monarda didyma* | Beeblam | | 15 |
| *Monarda fistulosa* | Wild bergamot | | 14, 16, 251 |
| *Monarda punctata* | Horsemint | | 16 |
| *Nepeta hederacea* | Gill-over-the-ground | | 16 |
| *Prunella vulgaris* | Heal-all | | 16, 34 |
| *Pynanthemum* spp. | Mountain mint | | 16 |
| *Salvia* spp. | Salvia | | 94, 173, 221 |
| *Stachys byzantina* | Lambs' ears | | 14, 15, 84, 251 |
| *Thymus serpyllum* | | 223 | |
| *Thymus serpyllum lanuginosus* | | 223 | |
| *Thymus serpyllum coccineus* | | 223 | |
| **LAURACEAE** | | | |
| *Lindera benzoin* | Spicebush | | 16, 17 |
| *Sassafras variifolium* | Sassafras | | 16 |

| | | | |
|---|---|---|---|
| **LOBELIACEAE** | | | |
| *Lobelia inflata* | Indian tobacco | | 16, 34 |
| *Lobelia sphilitica* | Great lobelia | | 16 |
| *Lobelia spicata* | Spiked lobelia | | 16 |
| **LYTHRACEAE** | | | |
| *Cuphea petiola* | Clammy cuphea | | 16, 34 |
| **MAGNOLIACEAE** | | | |
| *Liriodendron tulipifera* | Tulip tree | 244 | 16 |
| *Magnolia spp.* | Magnolia | 221 | |
| *Magnolia acuminata* | Cucumber tree | 16 | |
| *Magnolia soulangiana* | Saucer magnolia | 16, 67, 176 | |
| **MALVACEAE** | | | |
| *Alcea rosea* | Hollyhock | | 14, 15, 84, 251 |
| *Hibiscus* spp. | Hibiscus | | 251 |
| *Hibiscus esculentus* | Okra | 270 | |
| *Hibiscus syriacus* | Rose-of-Sharon | | 14, 84 |
| *Malva rotundifolia* | Common mallow | | 16 |
| **MENISPERMACEAE** | | | |
| *Menispermum canadense* | Moonseed | | 16 |
| **MORACEAE** | | | |
| *Morus alba* | White mulberry | | 17 |
| *Morus rubra* | Red mulberry | 16 | |
| **NYSSACEAE** | | | |
| *Nyssa sylvatica* | Black gum | | 16 |
| **OLEACEAE** | | | |
| *Chionanthus virginica* | Fringe-tree | 16 | |
| *Forsythia* spp. | Forsythia | | 16, 84, 176, 221, 251 |
| *Forsythia suspensa* | Weeping forsythia | | 14 |
| *Fraxinus americana* | White ash | 16, 244 | |
| *Fraxinus nigra* | Black ash | 16 | |
| *Ligustrum* sp. | Privet | 16, 67 | |
| *Syringa* spp. | Lilac | 16, 84, 270, 283 | 221 |
| *Syringa* x *persica* | Persian lilac | 176, 221 | |
| *Syringa vulgaris* | Common lilac | 176, 221 | |
| **ONAGRACEAE** | | | |
| *Circaea quadrisulcata* | | | 77 |
| *Oenethera* spp. | Evening primrose | | 16 |
| *Oenethera fruticosa* | Evening primrose | | 14, 15, 251 |
| **OXALIDACEAE** | | | |
| *Oxalis* spp. | Wood sorrel | | 16, 34 |

| | | | |
|---|---|---|---|
| *Oxalis corniculata* | Creeping lady's sorrel | | 14 |
| **PAEONIACEAE** | | | |
| *Paeonia spp.* | Peony | 16, 67, 84, 176, 221, 270 | |
| **PAPAVERACEAE** | | | |
| *Sanguinaria canadensis* | Bloodroot | | 14, 15, 84, 251 |
| **PLANTAGINACEAE** | | | |
| *Plantago major* | Common plantain | | 16 |
| *Plantago lanceolatum* | English plantain | | 16 |
| **PLATANACEAE** | | | |
| *Platanus occidentalis* | Sycamore | | 16, 17 |
| **PLUMBAGINACEAE** | | | |
| *Armeria vulgaris* var. *laucheana* | Thrift | 223 | |
| **POLEMONIACEAE** | | | |
| *Phlox paniculata* | Summer phlox | | 14, 15, 16, 84, 251, 283 |
| *Polemonium reptans.* | Jacob's ladder | 223 | 14, 84, 95, 251 |
| **POLYGALACEAE** | | | |
| *Polygala sanguinea* | Milkwort | | 16 |
| **POLYGONACEAE** | | | |
| *Fagopyrum* sp. | Buckwheat | | 34 |
| *Rumex* spp. | Dock | | 16 |
| **PORTULACACEAE** | | | |
| *Claytonia* spp. | Spring beauty | | 16 |
| *Claytonia virginica* | Spring beauty' | | 15 |
| **PRIMULACEAE** | | | |
| *Cyclamen* spp. | Cyclamen | | 15, 221 |
| *Primula* spp. | Primula | | 221 |
| *Primula* x *polyantha* | Polyanthus primrose | | 14, 15, 84, 251 |
| **RANUNCULACEAE** | | | |
| *Anemone* spp. | Thimbleweed | | 16 |
| *Anemone apennia* | | 221 | |
| *Anemone quinquefolia* | American wood anemone | | 15 |
| *Aquilegia caerulea* | Colorado columbine | 16 | |
| *Aquilegia canadensis* | Wild columbine | 16 | |
| *Clematis* spp. | Clematis | | 14, 84, 251 |
| *Clematis terniflora* | Sweet autumn clematis | | 16, 17 |
| *Clematis virginiana* | Virgin's bower | | 16 |
| *Eranthis hyemalis* | Winter aconite | | 14, 15, 84, 251 |
| *Helleborus* spp. | Hellebore | | 84, 221 |
| *Ranunculus* spp. | Crowfoot | | 16 |

| | | | |
|---|---|---|---|
| *Ranunculus ficaria* | Pilewort | | 221 |
| *Ranunculus repens* | Buttercup | 223 | |
| *Thalictrum* sp. | Meadow rue | | 15, 221 |
| **RHAMNACEAE** | | | |
| *Ceanothus americanus* | New Jersey tea | 16 | |
| **ROSACEAE** | | | |
| *Amelanchier canadensis* | Serviceberry | 16 | |
| *Aronia arbutifolia* | Red chokeberry | 16 | |
| *Cotoneaster* sp. | Cotoneaster | 84, 95 | |
| *Crataegus* spp. | Hawthorn | | 16 |
| *Cydonia oblonga* | Quince | | 16, 270 |
| *Geum* spp. Avens | 16 | | |
| *Kerria japonica* | Kerria | | 16, 17 |
| *Kerria japonica* 'Pleniflora' | Double-flower kerria | | 16 |
| *Malus* spp. | Apples | 16, 34, 84, 176, 210, 211, 221, 270 | 191 |
| *Malus* sp. cv. 'Stayman' | | | 176, 191 |
| *Malus* spp. | Crabapple | 67, 221 | 16, 67 |
| *Malus coronaria* | American crab | | 16 |
| *Malus hopa* | Hopa crabapple | 67, 176 | 16, 67 |
| *Physocarpus opulifolius* | Nine-bark | 16 | |
| *Potentilla canadensis* | Common cinquefoil | | 16 |
| *Potentilla fruticosa* | Shrubby cinquefoil | 16, 176, 221 | |
| *Prunus americana* | Wild plum | 16 | |
| *Prunus avium* | Sweet cherry | 283 | |
| *Prunus cerasus* | Sour cherry | 270 | |
| *Prunus pennsylvanicum* | Fire cherry | 16 | |
| *Prunus persica* | Peach | 211, 221 | 191 |
| *Prunus serotina* | Black cherry | | 16, 17 |
| *Prunus subhirtella* | Weeping Higan cherry | 16 | |
| *Prunus tomentosa* | Nanking cherry | 16 | |
| *Prunus virginiana* | Choke cherry | 16 | |
| *Pyracantha* sp. | Firethorn | 16 | |
| *Pyrus communis* | Pear | 84, 221 | |
| *Pyrus calleryana* | Callery pear | | 16 |
| *Ribes* spp. | Currant | | 16 |
| *Rosa* spp. | Wild rose | | 16, 176, 221 |
| *Rosa chinensis* | Fairy rose | 16 | |
| *Rosa minima* | Fairy rose | 16 | |
| *Rubus* spp. | Blackberry | 16, 34, 176, 221 | |
| *Rubus* spp. | Red raspberry | 221 | |
| *Rubus occidentalis* | Black raspberry | | 16, 34, 77, 95, 176, 221, 270 |
| *Rubus odoratus* | Purple flowering raspberry | 16 | |
| *Rubus procumbens* | Dewberry | | 251 |
| **RUBIACEAE** | | | |
| *Galium* spp. | Bedstraw | | 16, 34 |
| *Galium odoratum* | Sweet woodruff | | 14, 15, 251 |
| **RUTACEAE** | | | |

| | | | |
|---|---|---|---|
| *Zanthoxylum americanum* | Prickly ash | 16 | |
| **SALICACEAE** | | | |
| *Populus* sp. | Poplar | | 17 |
| *Salix nigra* | Black willow | 16 | |
| **SAMBUCACEAE** | | | |
| *Sambucus canadensis* | Common elderberry | 16 | |
| **SAPINDACEAE** | | | |
| *Koelreuteria paniculata* | Goldenrain-tree | | 16, 17 |
| **SAXIFRAGACEAE** | | | |
| *Astilbe* spp. | False spiraea | | 14, 15, 84, 95, 251 |
| *Heuchera* spp. | Coral bells | 16 | 15, 16, 221 |
| *Heuchera* x *brizoides* 'Pluie de feu' | Coral bells | | 14, 84 |
| *Hydrangea* sp. | Hydrangea | 16, 283 | |
| *Hydrangea arborescens* | Wild hydrangea | | 16, 84, 95 |
| *Philadelphus* spp. | Mock orange | | 95, 221 |
| **SCROPHULARIACEAE** | | | |
| *Verbascum blattaria* | Moth mullein | | 16 |
| *Verbascum thapsus* | Common mullein | | 16 |
| *Veronica filiformis* | Creeping veronica | | 14 |
| *Veronica officinalis* | Common speedwell | | 16 |
| **SIMAROUBACEAE** | | | |
| *Ailanthus glandulosa* | Tree of heaven | | 16 |
| **SOLANACEAE** | | | |
| *Capsicum annuum* | Pepper | 16, 84, 176, 221 | |
| *Lycopersicon esculentum* | Tomato | 16, 34, 84, 176, 221, 210, 211, 270, 283 | |
| *Nicotiana tabaccum* | Tobacco | 67 | |
| *Physalis* spp. | Ground cherry | | 16 |
| *Solanum aviculare* | Nightshade | | 221 |
| *Solanum melongena* | Eggplant | 16 | |
| *Solanum tuberosum* | Potato | 16, 34, 84, 176, 210, 211, 270 | |
| **STAPHYLEACEAE** | | | |
| *Staphylea trifolia* | Bladder nut | 16 | |
| **STYRACACEAE** | | | |
| *Halesia carolina* | Carolina silverbell | | 16, 17 |
| **THYMELEACEAE** | | | |
| *Daphne mezereum* | Daphne | | 14, 84, 251 |

| | | | |
|---|---|---|---|
| **TILIACEAE** | | | |
| *Tilia americana* | Basswood | 16, 67 | |
| *Tilia heterophylla* | White basswood | 16 | |
| *Tilia platyphyllos* | Bigleaf linden | | 16, 17 |
| **ULMACEAE** | | | |
| *Celtis occidentalis* | Hackberry | 67 | 16, 17 |
| *Ulmus americana* | American elm | | 16 |
| *Ulmus fulva* | Slippery elm | 16 | |
| **URTICACEAE** | | | |
| *Pilea pumila* | Clearweed | | 16 |
| **VIOLACEAE** | | | |
| *Viola* spp. | Violet | | 16, 34, 270 |
| *Viola canadensis* | Canada violet | | 14, 15, 84, 251 |
| *Viola cornuta* | Horned violet | | 14, 15, 84, 251 |
| *Viola sororia* | Woody blue violet | | 14, 84, 251 |
| *Viola* x *wittrockiana* | Pansy | | 14, 84, 251, 283 |
| **VITACEAE** | | | |
| *Pathenocissus quinquefolia* | Virgina creeper | | 14, 16, 34, 84, 176, 221, 251, 270 |
| *Vitis* spp. | Wild grape | | 16, 34, 176, 221, 270 |
| *Vitis vinifera* | Grape | 125 | |

## 5.4. Soil effects

A central issue in assessing the importance of juglone in allelopathy has been its longevity and movement in the soil. Juglone can persist in the soil for more than a year following tree removal, particularly if the stump has not been killed (221). Fisher (89) investigated three 22-25 year-old mixed plantations of *J. nigra* and *Pinus strobus* and *P. resinosa* in southwestern Ontario, Canada. In each plantation, three soil types with different drainage were represented. Pines growing near walnut trees on the well drained Brant soil showed no effects; those on the imperfectly drained Tuscola soil showed markedly reduced growth and those on the poorly drained Colwood soil were all dead. Fisher made no attempt to assess juglone levels in these soils but conducted an experiment by adding a fixed amount of juglone to the Brant soil maintained as either "wet" or "dry" and monitored its concentration for 90 days using bioassay. The dry soil lost its phytotoxicity after 30 days and juglone was not detectable after 60 days, whereas the wet soil continued to inhibit seedling growth and harbour juglone through the entire 90 days. Determinations of juglone in the field by Ponder and Tadros (227) at an upland site in southern Illinois showed that there was a gradient of juglone concentration away from a walnut tree and downward in the soil, with a maximal mean value of 3.95 μg/g (about 2 x $10^{-5}$ M) soil in topsoil (0-8 cm). A comparison of mixed plantings of black walnut and autumn-olive (*Eleagnus umbellata*) with walnut and European black alder (*Alnus glutinosa*) on similar soils revealed a significantly different juglone regime, likely caused by differing microenvironmental and microbiological conditions (226, 227). Higher juglone levels in black alder mixed plantings were consistent with the earlier decline of this species compared to autumn-olive. It was also found that nodulation in *Eleagnus angustifolia* co-planted with *J. nigra* did not occur when planted on bottomland soils, whereas there was good nodulation in upland soil; whether this difference is related to differing juglone regimes in the soil was not studied (332). De Scisciolo *et al.* (77) investigated the seasonal variation of juglone in soil, finding that the pattern conformed with juglone levels generally reported in the plant parts, with peaks in spring and autumn.

An often forgotten fact is that the effect of walnut trees seems to develop with maturation of the trees and, thus, may not be a problem in young plantings. According to Rietveld (244), there is a build-up period of 12-25 years before the effects of juglone may be noticeable. It is frequently observed that walnut may be grown successfully in the company of a nurse species such as *Alnus glutinosa*, *Eleagnus umbellata* or even pine for several years before any damage is apparent (244).

Another little studied aspect is the effect of juglone on soil arthropods and soil formation in general; the soil under walnut is likely to be different from neighbouring soils because of juglone or other factors. Brooks (32), in his survey of black walnut sites, found that soil under walnut was uniformly more alkaline, with differences in pH of up to 0.7. Wood and bark particles from trees containing juglone, *Carya illinoiensis* and *Juglans nigra*, are reported to decompose much more slowly than those from other hardwood species (4) and earthworms have been recorded as being scarce in walnut areas (176). Summers and Lussenhop (286) found that cores of walnut soil, when removed beyond the influence of the walnut canopy, increased in both arthropod number and diversity. Moreover, the authors concluded that the greater amount of soil organic matter associated with walnut could be ascribed to the general retardation of decomposer organisms.

The fate of juglone in soil has been surprisingly little studied until recently. It has been suggested that juglone levels in soil may decline as juglone becomes incorporated into soil organic matter (188, 253), as juglone has been reported in degradation products of humic acids from under walnut (47), or sorbed onto colloidal particles (89). The suggestion has been supported in part by the findings showing the low recovery of juglone after it had been added to sterile soil (77). This would also explain short-term inhibition as found, for example, by Conrad (59). It has also been suggested that the seeming variability of *Juglans* allelopathy may, in part, be due to variation in the ability of neighbouring plants to take up and detoxify juglone from the soil (296).

Rettenmaier *et al.* (240), in Germany, first discovered in black walnut soil an aerobic, motile Gram-negative rod-bacterium, identified as *Pseudomonas putida* J1, capable of metabolising juglone; further work showed a second strain *P. putida* J2 was able to degrade jugone (202). Given a glucose source, they could convert juglone stepwise to 2-hydroxymuconic acid. Schmidt (255) in the U.S. demonstrated that a bacterium, identified also as *Pseudomonas*, collected from walnut soil, was capable of rapidly metabolising juglone. His research suggested that, under aerobic conditions, juglone was unlikely to persist in soils at significant concentrations as the bacterium had a high affinity for juglone. This point is noteworthy as it indicates that measurements of soil juglone must be done more or less immediately to have any meaning, as extractable juglone levels can decline within a relatively short period of time (< 4 h) and can be reduced to <1% of original concentration within 43 h (77). Williamson and Weidenhamer (325) argued that, while *Pseudomonas* may be an effective sink for juglone, it should be remembered that the juglone production is continuous, and that plant roots also may act as juglone sinks and thus compete for soil juglone. Furthermore, they observed that the products of juglone degradation through *Pseudomonas* remain largely unknown, and these in themselves may be allelopathic. Schmidt (256) replied that, despite these uncertainties, there remains no clear evidence that juglone in soil causes allelopathic inhibition, a position which he recently restated (257).

Finally, another problem which confronts researchers is the mobility of juglone in soil. Almost all determinations of soil juglone have been performed through extraction of soil with chloroform. Experiments attempting to recover juglone (50-200 μg) added to 100 g soil demonstrated that rapid subsequent aqueous extraction 10 min later yielded less than 1% of the added juglone (77). Weidenhamer *et al.* (316) state that the solubility of juglone is 52 ppm or about 3.5 mM, which is certainly adequate to cause severe growth inhibition, but it would seem that juglone becomes preferentially adsorbed by soil particles or organic matter.

## 6. DISCUSSION

While the genus *Juglans* provides what are probably the most widely accepted examples of allelopathic plants , it must be concluded that there still is no unambiguous demonstration of its effect. In a previous paper (326), I have argued that there are six criteria required to demonstrate allelopathy: (A) a pattern of inhibition (or association) of one species with another, (B) the putative donor plant must produce biologically active substances, (C) the putative donor must have a mode of release of allelochemicals into the environment, (D) there must be a mode of allelochemical transport and/or accumulation in the environment, (E) the receiver plant must have some means of allelochemical uptake and (F) the observed symptoms and pattern of growth cannot be explained solely by physical or other biotic factors, such as competition or herbivory.

What is clear in the case of walnut is that there is well known (although not that well documented) interaction with several plant species. The species of walnut are known to contain substantial quantities of naphthoquinones, particularly active in the form of juglone, as well as other phenolic compounds. It is less clear how exactly juglone is released into the environment, although most accounts agree that it is released as a water-soluble glycoside of hydrojuglone, which is then hydrolysed and oxidised to form the active juglone. However, juglone is not particularly mobile in the soil and it appears that it is readily adsorbed by soil organic matter, nearby roots, or bacteria. It has also been argued that, as juglone is rapidly metabolised by soil bacteria, it is unlikely to ever reach concentrations in soil, and consequently in roots, sufficient to cause any appreciable effect. Despite attempts (e.g. 268), no one has as yet demonstrated that juglone is actually taken up by plant roots, although there are numerous glasshouse experiments which provide data on the effects of juglone on plant growth, particularly in aqueous culture.

There is certainly too much evidence to conclude that walnut has no chemical effect on neighbouring plants. However, it certainly remains for more and better work to be done. Many questions need to be answered through more critical work. For example, what is the effect of walnut in its natural environment? How great is intraspecific variation in juglone production? How does juglone enter a receptor plant? Is there any correlation between juglone concentration in walnut tissue and in soil and receptor plant response? Will investment in juglone research lead to lead to tangible benefits in agriculture, forestry, pharmacy or other areas?

## ACKNOWLEDGEMENTS

I wish to thank the following individuals who generously assisted in accessing resources:
Mr. Abdul Ghafoor Abdul Raheem, Melbourne Institute of Asian Languages and Societies, University of Melbourne, Prof. Toufic Fahd, Strasbourg, France, Ms Diane Forrest, University of California at Davis, Mr James Cornelius, Illinois State Historical Survey, University of Illinois - Urbana-Champaign, Mr. Bob Sickles, Iowa State University, Ames, Dr. Jerry Van Sambeek, USDA Forest Service, North Central Forest Experiment Station, Missouri, Mr. Gary Austin, Morehead State University, Kentucky, Prof. Marsha Fanning, Lenoir-Rhyne College, North Carolina, Mr. Paul Holmer, Southern Connecticut State University

## REFERENCES

1. Ajao, B. (1983). *Effects of Juglone (5-4-1 naphthoquinone) on Callus Initiation on Pointsettia Cuttings (Euphorbia pulcherrima Willd.).* M.Sc. thesis, Western Illinois University.

2. Albertus Magnus (1867). *De Vegetabilibus.* Berlin: E. Reiner.

3. Alkhawajah, A.M. (1997). Studies on the antimicrobial activity of *Juglans regia*. *American Journal of Chinese Medicine* **25** : 175-180.

4. Allison, F.E. and Murphy, R.M. (1962). Comparative rates of decomposition in soil of wood and bark particles of several hardwood species. *Soil Science Society of America Proceedings* **26**: 463-466.

5. Althen, F.W. von (1968). Incompatability of black walnut and red pine. *Canadian Department of Fishery and Forestry Bimonthly Research Notes* **24** : 19.

6. Althen, F.W. von (1976). *Ten-year Results of Thinning and Fertilizing of a Pole-sized Black Walnut Plantation.* Report O-X-245, Great Lakes Forest Research Centre, Canada. 22 pp.

7. Anonymous (1871). Does black walnut destroy fruit trees? *Pacific Rural Press* 1 July : 403

8. Anonymous (1883). Poison in walnut. *Forestry; a magazine for the country* 7: 234.

9. Anonymous (1926). Is the walnut poison? *Washington Star* **1926**(August 2): 8.

10. Anonymous (1929a). Black walnut tree effect upon plant life. *American Nut Journal* **31**: 28.

11. Anonymous (1929b). Walnut poison isolated. *New York Times* 10 Feb : X. 11.

12. Anonymous (1929c). Would hide criticism of black walnut tree. *American Nut Journal* **31** : 91.

13.* Anonymous (1995). Walnut and butternut toxicity. *Eau Claire County Extension Green Pages* **8**(4): 6-8

14.* Anonymous (1996). *Walnut Toxicity.* Michigan State University Extension.

15.* Anonymous (1998a). *Gardening Dilemnas: Under the Walnut Tree.* Silk Purse Farm Perennials

16.* Anonymous (1998b). *Black walnut toxicity. Green Tips.* Department of Horticulture, Michigan State University **GT-1025**.

17.* Anonymous (1998c). *Black walnut toxicity*. Dawes Arboretum.

18.* Anonymous (1998d). *Walnut toxicity*. Geocities.

19. Arey, J., Wilner, A.M. Atkinson, R., Aschman, S.M., Long, W.D., Morrison, C.L. and Olszyk, D.M. (1991). Terpenes emitted from agricultural species found in California's Central Valley. *Journal of Geophysical Research (Atmosphere)* **96**: 9329-9336.

20. Auyong, T.K., Westfall, B.A. and Russell, R.L. (1963). Pharmacological aspects of juglone. *Toxicon* **1** : 235-239.

21. Aynehchi, Y., Dehpoor, A.R. and Mahmodian, M. (1973). Juglone: the echtiotoxic principle of *Pterocarya fraxinifolia*. *Phytochemistry* **12**: 3001-3002.

22. Bauckmann, M. (1974). Grasmischungen für Walnussanlagen. *Mitteilungen Rebe und Wein, Obstbau und Früchteverwertung* **24**: 379-384.

23. Berestetskii, O.A. (1974). Toxicosis of orchard soils in dependence on ecological conditions and biological peculiarities of fruit-bearing plants [Russian]. In: *Fiziologo-biokhimicheskie Osnovy Vzaimodeistviya Rastenii v Fitotsenozakh*. (Ed., A.M. Grodzinskii), pp. 47-50. Kiev : Naukova Dumka.

24. Bhatt, B.P., Kaletha, M.S. and Todaria, N.P. (1997). Allelopathic exclusion of understorey crops by agroforestry trees of Garhwal Himalayas. *Allelopathy Journal* **4** : 321-328.

25. Bhatt, B.P. and Todaria, N.P. (1992). Studies on allelopathic exclusion of understorey by some agroforestry tree crops of Garhwal Himalyaya. In: *Allelopathy in Agroecosystems* (Eds., P. Tauro and S.S. Narwal), p. 129. Hisar : Haryana Agricultural University.

26. Bhuyan, K.C., Bhuyan, D.K. and Podos, S.M. (1991). Free radical enhancer xenobiotic is an inducer of cataract in rabbit. *Free Radical Research Communications* **12-13**: 609-620.

27. Binder, R.G., Benson, M.E. and Flath, R.A. (1989). Eight 1,4-naphthoquinones from *Juglans*. *Phytochemistry* **28** : 2799-2801.

28. Bixby, W.G. (1929). Black walnut tree's effects explained. *American Nut Journal* **1929**(August): 51.

29. Blagonravova, L.N. and Shcherbanovskii, L.R. (1975). Effect of 1,4-naphthaquinones and saponins on the activity of polyphenoloxidase (in vitro) [Russian]. In: *Fiziologo-biokhimicheskie Osnovy Vzaimodeistviya Rastenii v Fitotsenozakh*. (Ed., A.M. Grodzinskii). **6**: 37-39. Kiev : Naukova Dumka.

30. Blaim, K. (1962). The presence of nicotine in plants. *Flora* **152**: 171-172.

31. Bloszyk, E. Nawrot, J., Harinatha, J. Drozdz, B. and Chmielewicz, Z. (1990). Effectiveness of antifeedants of plant origin in protection of packaging materials against storage insects. *Journal of Applied Entomology* **110**: 96-100.

32. Bode, H.R. (1958). Beiträge zur Kenntnis allelopathischer Ercheinungen bei einigen Juglandaceen. *Planta* **51** : 440-480.

33. Boes, T.K. (1985). *Disparate Modes of Action of Juglone in the Respiratory Systems of Sensitive and Resistant Plants*. M.Sc. thesis, Kansas State University.

34. Boes, T.K. (1986). Allelopathy: chemical interaction between plants. *American Nurseryman* **163** : 67-72.

35. Borazjani, A. (1981). *Occurrence of Juglone Among Walnuts and Hickories: Seasonal Variations, Presence Among Tissues, Translocation, and the Influence of Growth Regulators on Concentrations*. Ph.D. thesis, Mississippi State University.

36. Borazjani, A., Graves, C.H. and Hedin, P.A. (1983). A survey of juglone levels among walnuts and hickories. *Pecan Quarterly* **17**(1) : 9-13.

37. Borazjani, A., Graves, C.H. and Hedin, P.A. (1985). Occurrence of juglone in various tissues of pecan and related species. *Phytopathology* **75** : 1419-1421.

38. Bratton, G.F. (1974). *The Role and Allelopathic Effects of Juglans nigra in old field succession.* M.Sc thesis. Emporia, Kansas: Kansas State College.

39. Brinkworth, R.J. and Fairlie, D.P. (1995). Hydroquinones are competitive non-peptide inhibitors of HIV-1 proteinase. *Biochimica et Biophysica Acta* **1253**: 5-8.

40. Brissemoret, A. and Michaud, J. (1917). Sur une nouvelle classe de medicament de la peau: les quinones peroxydes. *Bulletin Géneral de Therapeutique Médicale et Chirurgicale* **169**: 759-766.

41. Broda, B., Jaroniewski, W. and Swiatek, L. (1960). Occurrence of caffeic acid in some medicinal plants. *Acta Poloniae Pharmaceutica* **17**: 301-306.

42. Brooks, M.G. (1951). Effects of black walnut trees and their products on other vegetation. *West Virginia Agricultural Experiment Station Bulletin* **347** : 1-37.

43. Brown, B.I. (1942). Injurious influence of bark of black walnut on seedlings of tomato and alfalfa. *North Nut Growers Association Annual Report* **33** : 97-102.

44. Brown, O.R. and Green, T.J. (1987). Oxidant stress: a possible approach to malaria chemotherapy. *Medical Science Research* **15**: 9-12.

45. Bruner, M.H. (1969). Walnut and pine don't mix. *Forest Farmer* **28** : 15.

46. Campbell, G.E. and Dawson, J.O. (1989). Growth, yield, and value projections for black walnut interplantings with black alder and autumn olive. *Northern Journal of Applied Forestry* **6** : 129-132.

47. Carballas, T., Andreux, F. and Metche, M. (1972). Controlling effect of some litter components in the formation and properties of the organic matter of a calacareous brown soil. *Bulletin de l'Ecole Nationale Supérieure d'Agronomie et des Industries Alimentaires* **14**: 245-261.

48. Cardano, G. (1550). *De Subtilitate.* Norimberg: I. Petreium.

49. Carmean, W.H., Clark, F.B. Williams, R.D., Hannah, P.R. (1976). Hardwoods planted in old fields favored by prior tree cover. *USDA Forest Service Research Paper* **NC-134**: 1-16.

50. Carnat, A., Petitjean-Freytet, C., Muller, D. and Lamaison, J.-L. (1993). Percentage of principal components in the leaves of walnut *Juglans regia* L. *Plantes Medicinales et Phytothérapie* **26**: 332-339.

51. Case, P.J. and Funk, D.T. (1978). The complex effects of juglone on the growth of pine, spruce, and larch seedlings. In: *Proceedings of the Fifth North American Forest Biology Workshop* (Eds., C.A. Hollis and A.E. Squillace), p. 422.

52. Charlot, G and Radix, P. (1993). Bacteriose du noyer. Composés phenoliques et resistance. *Infos Paris* **94**: 31-32.

53. Chary, V.S.N. and Rao, S.S.R. (1994). The effect of certain phenolics on senescence of radish (*Raphanus sativus* L.) leaf discs. *Journal of Phytological Research* **7**: 41-44.

54. Chen, R. and Pignatello, J.J. (1997). Role of quinone intermediates as electron shuttles in Fenton and photoassisted Fenton oxidations of aromatic compounds. *Environmental Science and Technology* **31**: 2399-2406.

55. Clark, A.M., Jurgens, T.M. and Hufford, C.D. (1990). Antimicrobial activity of juglone. *Phytotherapy Research* **4**: 11-14.

56. Clark, P.B. and Williams, R.D. (1979). Black walnut growth increased by interplanting with nitrogen-fixing shrubs and trees. *Proceedings Indian Academy of Science* **88**: 88-91

57. Cline, S. and Neely, D. (1984). Relationship between juvenile-leaf resistance to anthracnose and the presence of juglone and hydrojuglone glucoside in black walnut. *Phytopathology* **74** : 185-188.

58. Coder, K.D. (1983). Seasonal changes of juglone potential in leaves of black walnut (*Juglans nigra* L.) *Journal of Chemical Ecology* **9** : 1203-1212.

59. Conrad, O.W. (1973). *The Effects of Water Extracts From Juglans nigra L. on the germination of Native Deciduous Tree Species.* M.Sc. thesis, Morehead, Kentucky, Morehead State University.

60. Compton, M.E. and Preece, J.E. (1988). Effect of phenolic compounds on tobacco callus and blackberry shoot cultures. *Journal of the American Society for Horticultural Science* **113**: 160-163.

61. Cook, M.T. (1921). Wilting caused by walnut trees. *Phytopathology* **11** : 346.

62. Crescenzi, P. di (1471). *De Agricultura Vulgare*. Venezia: Johannes Rubeus.

63. Crosby, A.L. (1976). Walnut trees: these trees may be hazardous to the health of their neighbouring plants. *Green Scene* **1976** (Nov.) : 12-13.

64. Crozier, A.A. (1891). *Popular Errors About Plants*. Ann Arbor : Register Publishing Co.

65 Daglish, C. (1950a). The isolation and identification of a hydrojuglone glucoside occurring in the walnut. *Biochemistry Journal* **47** : 452-457

66. Daglish, C. (1950b). The determination and occurrence of a hydrojuglone glucoside in the walnut. *Biochemistry Journal* **47** : 459-462.

67. Dana, M.N. and Lerner, B.R. (1986). Black walnut toxicity. *Home Yard & Garden* **HO-193**. (*)

68. Daugherty, W., Smith, S., Wigal, C., Verhoek, S. and Williams, S. (1995). Distribution of 5-hydroxy-1,4-naphthoquinone and other naphthoquinone derivatives in the Juglandaceae (walnut family) and related families. *Current Topics in Plant Physiology* **15** : 335-337.

69. Davidson, J. (1939). Some unanswered questions. *Northern Nut Growers Association Annual Report* **30** : 58-66.

70. Davis, E.F. (1928). .The toxic principle of *Juglans nigra* as identified with synthetic juglone, and its effects on tomato and alfalfa plants. *American Journal of Botany* **15**: 620.

71. Dawson, J.O., Knowlton, S. and Sun, S.H. (1981). The effect of juglone concentration on the growth of *Frankia in vitro*. Forestry Research Report, Department of Forestry, University of Illinois 81-2.

72. Dawson, J.O. and Seymour, P.E. (1983). Effects of juglone concentration on growth in vitro of *Frankia* Ar13 and *Rhizobium japonicum* Strain 71. *Journal of Chemical Ecology* **9** : 1175-1184.

73. Dawson, J.O. and Van Sambeek, J.W. (1993). Interplanting woody nurse crops promotes differential growth of black walnut saplings. In: *Proceedings of the 9th Central Hardwood Forest Conference* (Eds., A.R. Gillespie, G.R. Parker, P.E. Pope and G. Rink), pp. 455-464. *USDA Forest Service General Technical Report* **NC-161**.

74. DePalma, N.K. (1982). *Allelopathy in the Juglandaceae*. M.Sc. thesis, Southern Connecticut State College.

75. DePalma, N.K. (1983). Allelopathic effects of butternut and black walnut seedlings on tomatoes. *Northern Nut Growers Association Annual Report* **74** : 123-129.

76. De Scisciolo, B. (1988). *The Seasonal Pattern of Juglone in Soil Beneath Juglans nigra (black walnut) and the Influence of J. nigra on Understory Vegetation*. M.Sc. thesis. Syracuse: State University of New York.

77. De Scisciolo, B., Leopold, D.J. and Walton, D.C. (1990). Seasonal patterns of juglone in soil beneath *Juglans nigra* (black walnut) and influence of *J. nigra* on understory vegetation. *Journal of Chemical Ecology* **16** : 1111-1130.

78. Didry, N., Dubreuil, L. and Pinkas, M. (1994). Activity of anthroquinonic and naphthoquinonic compounds on oral bacteria. *Pharmazie* **49**: 681-683.

79. Didry, N., Pinkas, M. and Dubreuil, L. (1986). Antimicrobial activity of some naphthoquinones found in plants. *Annales de Pharmacie Francais* **44** : 73-78.

80. Diehl, S.V., Graves, C.H. and Hedin, P.A. (1992). Cytochemical responses of pecan to *Cladosporium caryigenum*: *in situ* localization and quantification of fungitoxic phenols. *Phytopathology* **82** : 1037-1041.

81. Dixon, R.K. (1992). Seed source and vesicular-arbuscular mycorrhizal symbiont affects growth of *Juglans nigra* seedlings. *New Forests* **2**: 203-211

82. Dornbos, D.L. and Spencer, G.F. (1990). Natural products phytotoxicity: a bioassay suitable for small quantities of slightly water-soluble compounds. *Journal of Chemical Ecology* **16** : 339-352.

83. Duroux, L., Delmotte, F.M., Lancelin, J.M., Keravis, G. and Jayallemand, C. (1998). Insight into naphthoquinone metabolism. β-glucosidase-catalysed hydrolysis of hydrojuglone β-D-glucopyrenoside. *Biochemical Journal* **333**: 275-283.

84. Ellis, D.J. (1995). Black walnut toxicity. *American Horticultural Society Resource Bulletin* **111**: 1-3.

85. Estienne, C. (1689). *l'Agriculture et Maison Rustique*. Lyon: Claude Carteron & Charles Amy

86. Evelyn, J. (1664). *Sylva, or, a Discourse of Forest Trees*. London : Royal Society.

87. Fayle, D.C.F. (1976). "Take it off!". *Forestry Chronicle* **52** : 265.

88. Fisher, A.T. (1995). *Allelopathic Effects of Leaf Extracts of Juglans nigra, Carya tomentosa and Carya illinoensis on Lettuce Seed Germination and Growth Correlated with HPLC Analysis*. Honors thesis. Hickory, North Carolina : Lenoir-Rhyne College.

89. Fisher, R.F. (1978). Juglone inhibits pine growth under certain moisture regimes. *Soil Science Society of America Journal* **42** : 801-803.

90. Floreani, M., Forlin, A., Bellin, S., and Carpendo, F. (1995). Structure-activity relationship for the inhibition of cardiac sarcoplasmic reticulum Ca++ ATPase activity by naphthoquinones. *Biochemestry and Molecular Biology International* **37**: 757-763.

91. Folterer, R. and Fleming, M.W. (1991). The effects of plumbagin on development of the parasitic nematodes *Haemonchus contortus* and *Ascaris suum*. *Comparative Biochemistry and Physiology C. Comparative Pharmacology and Toxicology* **100:** 539-542.

92. Fregoni, M. (1962). La successione delle piante arboree: problemi relativi al reimpiante dei fruttteti e dei vivai. *Frutticoltura* **24**: 463-471.

93. Freidrich, J.M. and Dawson, J.O. (1984). Soil nitrogen concentration and *Juglans nigra* growth in mixed plots with nitrogen-fixing *Alnus, Eleagnus, Lespedesa* and *Robinia* species. *Canadian Journal of Forest Research* **14**: 864-868.

94. Fuchs, L. (1550). *l'Histoire des Plantes mis en Commentaires*. Lyon: B. Arnoulhet.

95. Fuchs, L. (1995). Making peace with black walnuts. *American Horticulturalist* **74** : 14-15.

96. Fujimoto, Y., Yokoyama, E., Takahashi, T., Uzawa, J., Morooka, N., Tsunodo, H. and Tatsuno, T. (1986). Studies on the metabolites of *Penicillium diversum* var. *aureum*. I. *Chemical and Pharmaceutical Bulletin (Tokyo)* **34**: 1497-1500.

97. Funk, D.T., Case, P.J., Rietveld, W.J. and Phares, R.E. (1979). Effect of juglone on the growth of coniferous seedlings. *Forest Science* **25** : 452-454.

98. Funk, D.T., Schlesinger, R.C. and Ponder, F. (1979). Autumn-olive as a nurse plant for black walnut. *Botanical Gazette* **140**(Suppl) : S110-114.

99.* Funt, R.C. and Martin, J. (1993). Black walnut toxicity to plants, humans and horses. Ohio State University Extension Factsheet HYG-1148-93.

100. Gabriel, W.J. (1975). Allelopathic effects of black walnut on white birches. *Journal of Forestry* **73** : 234-237.

101. Galusha, O.B. (1870). O.B. Galusha report *ad-interim* - apples. *Transactions of the Illinois State Horticultural Society*, New Series **4**: 78-86.

102. Gäumann, E. and von Arx, A. (1947). Antibiotics as plant plasma poisons. II. *Berichte der schweizerischen botanischen Gesellschaft* **57** : 174-183.

103. Gibbs, R.D. (1974). *Chemotaxonomy of Flowering Plants*. **4** Volumes. Montreal : McGill-Queen's University Press..

104. Gilbert, B.L., Baker, J.E. and Norris, D.M. (1967). Juglone (5-hydroxy-1,4-naphthoquinone) from Carya ovata a deterrant to feeding by Scolytus multistriatus. *Journal of Insect Physiology* **13**: 1453-

105. Girzu, M., Fraisse, D., Carnat, A.P., Carnat, A. and Lamaison, J.-L. (1998). High-performance liquid chromatographic method for the determination of juglone in fresh walnut leaves. *Journal of Chromatography A* **805**: 315-318.

106. Gordon, A.M. and Williams, P.A. (1988). Intercropping valuable hardwood tree species and agricultural crops. *Agrologist* **17**(3) : 12-14.

107. Gordon, J.H. (1981). Persimmons under black walnuts. *Pomona* **14**(4) : 220.

108. Governor, H.L., Schultz, J.C. and Appel, H.M. (1997). Impact of dietary allelochemicals on gypsy moth (*Lymantria dispar*) caterpillars: importance of midgut alkalinity. *Journal of Insect Physiology* **43**: 1169-1175.

109. Graves, C.H., Hedin, P.A. and Langhans, V.E. (1979). A survey of juglone levels among pecan, hickory and walnut. In: *Proceedings Annual Convention of Southeast Pecan Growers Association*, pp. 103-111. Hilton Head, South Carolina : Southeastern Pecan Growers Association.

110. Greene, K.W. (1929). The toxic ? effect of the black walnut. *Nut Grower(Downington, Pa.)* 7(3): 1-3.

111. Greene, K.W. (1930). The toxic (?) effect of the black walnut. *Northern Nut Growers Association Annual Report* **20** : 152-157.

112. Gries, G.A. (1943ca). Juglone (5-hydroxy-1,4-naphthoquinone) - a promising fungicide. *Phytopathology* **33** : 1112.

113. Gries, G.A. (1943b). Juglone - the active agent in walnut toxicity. *Northern Nut Growers Association Annual Report* **34** : 52-55.

114. Grümmer, G. (1955). *Die Gegenseitige Beeinflussung Höherer Pflanzen - Allelopathie.* Jena: Gustav Fischer.

115. Gueldner, R.C., Yates, I.E., Reilly, C.C., Wood, B.W. and Smith, M.T. (1994). Levels of a hydrojuglone glucoside in developing pecan leaves in relation to scab susceptibility. *Journal of the American Horticultural Society* **119**: 498-504.

116. Gujar, G.T., Rao, R.V.S. and Sankaram, A.V.B. (1994). Bioactivity of naturally occurring plumbagnoids against insects. *Phytophaga (Madras)* **6**: 117-119

117. Gupta, S.R., Ravindranath, B. and Seshadri, T.R. (1972). Polyphenols of *Juglans nigra*. *Phytochemistry* **11**: 2634-2636.

118. Haasis, F.W. (1930). Forest plantations at Biltmore, N.C. *USDA Miscellaneous Publication* **61** : 1-30.

119. Hartmann, H. (1981). Walnut roots in a chestnut garden. *The Nutshell* **34**(3): 6.

120. Hauser, C.E. (1982). *Allelopathic Effects of Festuca arundinacea on the Growth of Juglans nigra Seedlings.* M.Sc. thesis. Southwest Missouri State University.

121. Heckman, J.R. and Kluchinski, D. (1995). Soybean nodulation and nitrogen fixation on soil amended with plant residues. *Biology and Fertility of Soil* **20** : 284-288.

122. Hedin, P.A., Collum, D.H., Langhans, V.E. and Graves, C.H. (1980). Distribution of juglone and related compounds in pecan and their effect on *Fusicladium effusum*. *Journal of Agricultural and Food Chemistry* **28** : 340-342.

123. Hedin, P.A., Langhans, V.E. and Graves, C.H. (1979). Identification of juglone in pecan as possible factor of resistance to *Fusicladium effusum*. *Journal of Agricultural and Food Chemistry* **27** : 92-94.

124. Hedin, P.A., Neel, W.W., Burks, M.L. and Grimley, E. (1985). Evaluation of plant constituents associated with pecan *Phylloxera* gall formation. *Journal of Chemical Ecology* **11** : 473-484.

125. Hedrick, U.P. (1905). The relationship of plants in the orchard. *Proceedings of the Society for Horticultural Science* **1903** : 72-82.

126. Heimann, M.F. and Stevenson, W.R. (1982). Walnut and butternut toxicity. *University of Wisconsin Cooperative Extension Service Document* **A3182** : 1-2.

127. Hejl, A.M., Einhellig, F.A. and Rasmussen, J.A. (1993). Effects of juglone on growth, photosynthesis, and respiration. *Journal of Chemical Ecology* **19** : 559-568.

128. Hejl, A.M., Einhellig, F.A., Rasmussen, J.A. and Quah, S. (1993). Effects of sorgoleone and juglone on functions of isolated chloroplasts and mitochondria. In: *Plant Signals in Interactions with Other Organisms. Current Topics in Plant Physiology* vol. 11 (Eds., J.C. Schultz and I. Raskin). pp. 235-236. Rockville, Maryland : American Society of Plant Physiologists.

129. Herrera, G.A. (1513). *Obra de Agricultura*. Alcala de Henares : Arnas Guillen de Brocar.

130. Hershey, J.W. (1929). Some interesting data on the toxic effect of walnut species on themselves and each other. *Nut Grower (Downingtown, Pa.)* 7(4): 3.

131. Hirakawa, K., Ogive, E., Motoyoshiya, J. and Yajima, M. (1986). Naphthoquinones from Juglandaceae. *Phytochemistry* **25**: 1494-1495.

132. Ho, C.M., Wu, S.H. and Wu, C.C. (1990). Evaluation of the control of mosquitoes with insect growth regulators. *Kao Hsiung I Hsueh Ko Hsueh Tsa Chih* **6**: 366-374.

133. Hradilik, J., Herrmannova, L. and Fiserova, H. (1986). Effect of some phenolic compounds on growth correlations in flax (*Linum usitatissimum* L.). *Acta Universitatis Agriculturae Facultas Agronomica Brno* **34**(1) : 39-76.

134. Hussain, F., Ihsan, I. and Kil, B.-S. (1991). Allelopathic effects of walnut plants (*Juglans regia* L.) on four crop species. *Korean Journal of Botany* **34** : 93-100.

135. Ibn al-Awwam (1802). *Libro de Agricultura* (transl. J.A. Banqueri). Madrid: Impr. Real. Also published in Seville (1878) and Madrid (1988).

136. Ibn al-Awwam (1864-7). *Le Livre de l'Agriculture d'Ibn-al-Awam* (transl. Clement-Mullet). Paris: A Franck. Also published in Tunis (1977).

137. Ibn Wahshiyya. (1995). *L'Agriculture Nabateene. Traduction en arabe attribuee a Abu Bakr Ahmad b. 'Ali al-Kasdani connu sous le nom d'Ibn Wahsiyya (IV'Xe siecle). Tome II* (ed. T. Fahd). Damas: Institut Français de Damas.

138.* Jauron, R. (1992). Wilting tomatoes. *Horticulture & Home Pest News* 22 July: 127-129.

139.* Jauron, R (1995). Black walnut toxicity. *Horticulture & Hone Pest News* 26 May: 76.

140. Jay-Allemand, C., Doumas, P., Sotta, B., Tranvan, H., Miginiac, E. and Sandermann, H. (1995). Juvenility and physiology of rhizogenesis in two woody species (*Sequoia sempervirens* and *Juglans nigra* x *Juglans regia*). In: *Eurosylva: Contribution to Forest Tree Physiology. Final Workshop, Dourdan, France* (Ed. M. Bonnet-Masimbert), pp. 79-91.

141. Jay-Allemand, C., Peng, S., Capelli, P. and Cornu, D. (1993). Micropropagation of hybrid walnut trees: some factors involved in rooting. *Acta Horticulturae* **311**: 117-124.

142. Jensen, T.E. and Welbourne, F. (1962). The cytological effect of growth inhibitors on excised roots of *Vicia faba* and *Pisum sativum*. *Proceedings of the South Dakota Academy of Science* **41** : 131-136.

143. Jesaitis, R.G. and Krantz, A.J. (1972). Juglone: an organic chemistry-ecology interaction experiment. *Journal of Chemical Education* **49** : 436-437.

144. Johnson, K.S. and Felton, G.W. (1996). Physiological and dietary influences on midgut redox conditions in generalist Lepidopteran larvae. *Journal of Insect Physiology* **42**: 191-198.

145. Jones, L.R. and Morse, W.J. (1903). The shrubby cinquefoil as a weed. *Vermont Agricultural Experiment Station Annual Report* **16** : 173-179

146. Jose, S. (1997). *Interspecific Interactions in Alleycropping: the Physiology and Biogeochemistry (Nutrient Cycling, Allelopathy, Juglans nigra, Quercus rubra, Zea mays, Competition)*. Ph.D. thesis, Purdue University.

147. Jose, S., Benjamin, T., Stall, T., Gillespie, A.R., Hoover, W.L., Mengel, D.B., Seifert, J.R. and Biehle, D.J. (1997). Biology and economics of a black walnut-corn alley cropping system. In: *Knowledge for the Future of Black Walnut. Proceedings of the Fifth Black Walnut Symposium. USDA Forest Service General Technical Report* NC-191, pp. 203-208.

148. Kamei, H., Koide, T., Kojima, T., Hashimoto, Y. and Hasegawa, M. (1998). Inhibition of cell growth in culture by quinones. *Cancer Biotherapy and Radiopharmaceuticals* **13**: 185-188.

149. Kasumova, M.M. (1971). Fungicidal activity of phytoncides from green leaves and unripe pericarps of walnuts [Russian]. *Uchenye Zapiski Azerbaidzhenskii Meditsinskogo Instituta* **33** : 74-85.

150. Kessler, C.T. (1985). *The Allelopathic Effects of Juglone (5-hydroxy-1,4-naphthoquinone) on Freshwater Algal Growth.* M.Sc. thesis, Bloomsburg University.

151. Kessler, C.T. (1989). Effect of juglone on freshwater algal growth. *Journal of Chemical Ecology* **15** : 2127-2134.

152. Kessler, K.J. (1985). Companion planting of black walnut with autumn olive to control *Mycosphaerella* leaf spot of walnut. In: *Proceedings of the 5th Central Hardwood Forest Conference.*

153. Kessler, K.J. (1988). Companion planting of black walnut with autumn olive to control walnut anthracnose. *Phytopathology* **78**: 1606.

154. Kim, S.-H., Lee, K.-S., Son, J.-K., Je, G.H., Lee, J.-S., Lee, C.H. and Cheone, C.J. (1998). Cytotoxic compounds from the roots of *Juglans mandshurica. Journal of Natural Products* **61**: 643-645.

155. Kipkech, F.C. (1995). *The Effects of Sugar Maple (Acer saccharum Marsh.) and Black Walnut (Juglans nigra L.) on Soil Fertility: Preliminary Assessment of Their Agroforestry.* Ph.D. thesis, McGill University, Montreal.

156. Klusak, H. (1976). Changes of growth elongation in wheat and barley coleoptiles caused by some phenolic substances. *Biologia* (Bratislava) **31** : 283-286.

157. Koeppe, D.E. (1972). Some reactions of isolated corn mitochondria influenced by juglone. *Physiologia Plantarum* **27** : 87-94.

158. Kolesnichenko, M.V. (1968). *Biokhimicheskie Vzaimovliyaniya Drevesnykh Rastenii.* Moskva: Lesnaya Promyshlennost'

159. Kozhevnikov, I.G. (1978). Allelopathic potential of ornamental woody and shrubby plants [Russian]. In: *Problemy Allelopatii* (Ed., A.M. Grodzinskii), pp. 95-96. Kiev : Naukova Dumka.

160. Krajci, W.M. and Lynch, D.L. (1978). The inhibition of various micro-organisms by crude walnut hull extracts and juglone. *Microbios Letters* **4** : 175-181.

161. Kraus, P. (1942). Jabir Ibn Hayyam. Contribution à l'histoire des idées scientifiques dans l'Islam. *Mémoires Presentés à l'Institut d'Egypte* **45** : 1-406.

162. Kroeber, L. (1946). Pflanzenfreundschaften - Pflanzenfiendschaften. *Die Pharmazie* **1**: 225.

163. Lagrange, E. (1954). L'action bactericide de l'extrait des feuilles de *Juglans regia* L. [French]. *Comptes Rendus des seances de la Société de Biologie* **148** : 2097-2098.

164. Lagrange, E. (1956). L'action antibiotique de *Juglans regia* L. *Comptes Rendus des séances de la Société de Biologie* **150**: 613-615.

165. Langhans, V.E., Hedin, P.A. and Graves, C.H. (1978). Fungitoxic chemicals in pecan tissue. *Plant Disease Reporter* **62** : 894-898.

166. Lee, K.-C. (1967). *Nature and Occurrence of Juglone in Juglans nigra L.* M.Sc. thesis, Kansas State University.

167. Lee, K.C. and Campbell, R.W. (1969). Nature and occurrence of juglone in *Juglans nigra. Hortscience* **4** : 297-298.

168. Lembeck, F. and Skofitsch, G. (1984). Distribution of serotonin in *Juglans regia* seeds during ontogenetic development and germination. *Zeitschrift für Pflanzenphysiologie* **114**: 349-353

169. Lemberkovics, E., Hothelyi, F. and Hetesi, F. (1987). Some phytochemical characteristics of *Juglans regia* L. *Acta Pharmaceutica Hungarica* **57**(3/4) : 133-142.

170. Li, H.H., Nishimura, H., Hasegawa, K. and Mizutani, J. (1993). Some physiological effects and the possible mechanism of action of juglone in plants. *Zasso Kenkyu* **38** : 214-222.

171. MacDaniels, L.H. (1977). Black walnut toxicity. *New York Times* Sept 11 : 43.

172. MacDaniels, L.H. (1980). Further observations on the toxicity of black walnut on tomatoes and some other plants. *Northern Nut Growers Association Annual Report* **71**: 112-126.

173. MacDaniels, L.H. (1981). Eighty years with the black walnut. *Northern Nut Growers Association Annual Report* **72** : 147-152.

174. MacDaniels, L.H. (1982). Perspective on the black walnut toxicity problem - apparent allergies to man and horse. *Northern Nut Growers Association Annual Report* **73** :62-65.

175. MacDaniels, L.H. and Muenscher, W.C. (1941). Black walnut toxicity. *Northern Nut Growers Association Annual Report* **31** : 172-179.

176. MacDaniels, L.H. and Pinnow, D.L. (1976). Walnut toxicity, an unsolved problem. *Northern Nut Growers Association Annual Report* **67** : 114-122.

177. MacDaniels, L.H. and Pratt, A.J. (1982). Comparative effects of black walnut toxicity on tomatoes, potatoes and peppers. *Northern Nut Growers Association Annual Report* **73** : 57-62.

178. Mahajan, R., Kaur, D. and Bajaj, K.L. (1992). Nematacidal activity of phenolic compounds against *Meloidogyne incognita*. *Nematologia Mediteranea* **20**: 217-219.

179. Marichkova, L. and Kumanova, B. (1981). Isolation of flavonoids and some accompanying substances from the above-ground part of some *Astragalus centralpinus*, family Leguminosae [Russian]. *Problemy Farmacia* **9**: 63-74.

180. Marking, L.L. (1970). Juglone (5-hydroxy-1,4-naphthoquinone) as a fish toxicant). *Journal of the American Fish Society* **99**: 510.

181. Marking, L.L. (1971). Method of fish culture. U.S. Patent 3-602-194.

182. Marston, A., Msonthi, J.D. and Hostettmann, K. (1984). Naphthoquinones of *Diospyros usambarensis*: their molluscicidal and fungicidal activities. *Planta Medica* **50**: 279-280.

183. Martin, H. (1957). *Chemical Aspects of Ecology in Relation to Agriculture*. Ottawa: Canada Department of Agriculture.

184. Masciangioli, T.M., Wallace, J.W. and Bacon, J.R. (1993). Contributions to understanding the chemical arsenal of *Juglans nigra*: the isolation and identification of flavonoid constituents. *American Journal of Botany* **80** (6 Suppl.): 106.

185. Massey, A.B. (1925). Antagonism of the walnut (*Juglans nigra* L. and *J. cinerea* L.) in certain plant associations. *Phytopathology* **15** : 773-784.

186. Massey, A.B. (1928). Are nut trees poisonous to other trees and plants? *Flower Grower* **15** : 4.

187. Mathews, R.S. (1995). *Artemia salina* as a test organism for measuring superoxide-mediated toxicity. *Free Radicals in Biology and Medicine* **18**: 919-922.

188. Mathur, S.P. (1972). Spectroscopic and chemical evidence of quinones in soil humus. *Soil Science* **113**: 136-139.

189. Matsuda, K. and Sugawaro, F. (1980). Defensive secretion of chrysomelid larvae *Chrysomela vigintipunctata costella* (Marseul), *C. pupuli* L. and *Gastrolina depressa* Baly (Coleoptera: Chrysomelidae). *Applied Entomology and Zoology* **15** : 316-320.

190. Matsumoto, M., Misawi, S. and Chiba, S. (1998). Aromatic hydroxy compounds as inhibitors for protease of herpes simplex virus type 1, and their use as antiherpes agents [patent]. *Chemical Abstracts* **129**: 1043.

191. Mattoon, H.G. (1944). A commercial black walnut venture. *Northern Nut Growers Association Annual Report* **35** : 79-82.

192. Matveev, N.M. (1994). *Allelopatiya kak Faktor Ekologicheskoi Sredy*. Samara : Samarskoe Knizhnoe Izdatel'stvo.

193. McWhorter, Douglas, Bryant and Schroeder (1874). Discussion. *Transactions of the Illinois State Horticultural Society*, New.Series **8** : 66-67.

194. Melkania, N.P. (1984). Influence of leaf leachates of certain woody species on agricultural crops. *Indian Journal of Ecology* **11** : 82-86.

195. Miller, A.G. (1926). Walnuts and apples. *Farm Journal* **1926**(July) : 17.

196. Moir, M. and Thomson, R.H. (1973). Naphthoquinones in *Lomatia* species. *Phytochemistry* **12** : 1351-1353.

197. Molisch, H. (1937). *Der Einfluss einer Pflanze auf die Andere - Allelopathie*. Jena: Gustav Fischer.

198. Moseley, M.F. and Purves, W.K. (1974). *Botany in the Laboratory*. Santa Barbara : Hamilton Publishing Co.

199. Müller, W.-U. and Leistner, E. (1976). 1,4-naphthoquinone, an intermediate in juglone (5-hydroxy-1,4-naphthoquinone) biosynthesis. *Phytochemistry* **15**: 407-410.

200. Müller, W.-U. and Leistner, E. (1978a). Metabolic relation between naphthalene derivatives in *Juglans*. *Phytochemistry* **17** : 1735-1738.

201. Müller, W.-U. and Leistner, E. (1978b). Aglycones and glycosides of oxygenated naphthalenes and a glucosyltransferase from *Juglans*. *Phytochemistry* **17**: 1739-1742.

202. Müller, U. and Lingens, F. (1988). Degradation of 1,4-naphthoquinones by *Pseudomonas putida*. *Biological Chemistry Hoppe-Seyler* **369**: 1031-1043.

203. Nageshwar, G., Radhakrishnaiah,M. and Narayana, L.L. (1984). Chemotaxonomy of *Caesalpinia*. *Current Science* **53**; 813-814.

204. Naylor, C.W. (1930). *The Secret of the Singing Heart*. Warner Press.

205. Neave, I.A. and Dawson, J.O. (1989a). Juglone reduces growth, nitrogenase activity, and root respiration of actinorhizal black alder seedlings. *Journal of Chemical Ecology* **15** : 1823-1836.

206. Neave, I.A. and Dawson, J.O. (1989b). Juglone: effects on black alder physiology and its detoxification in soil. In: *The Continuing Quest for Quality*. Proceedings of the Fourth Black Walnut Symposium. (Ed., J.E. Phelps), pp. 182-192. Walnut Council.

207. Neuhauscarlisle, K., Vierling, W. and Wagner, H. (1997). Screening of plant extracts and plant constituents for calcium-channel blocking activity. *Phytomedicine* **4**: 67-71.

208. Norris, D.M. (1977). Role of repellants and deterrants in feeding of *Scolytus multistriatus*. In: *Host Plant Resistance to Pests*. (Ed., P.A. Hedin), pp. 215-230. Washington, D.C.: American Chemical Society.

209. Ohta, A., Sivalingam, P.M., Lin, S. and Ikekawa, N. (1973). Isolation of naphthazarin from walnut 'Onigurumi' and its inhibitory action on oxidative phosphorylation in mitochondria. *Toxicon* **11** : 235-241.

210. Orton, C.R. (1943). Epistle to the farm. *West Virginia Agricultural Experiment Station Bulletin* **307**: 1-56.

211. Orton, C.R. and Jenny, G. (1948). Research powers of the farm. *West Virginia Agricultural Experiment Station Bulletin* **334**: 3-35.

212. Pardhasaradhi, M. and Babu, M.H. (1978). A new bisjuglone from *Juglans regia* root bark. *Phytochemistry* **17**: 2042-2043.

213. Paschke, M.W., Dawson, J.O. and David, M.B. (1989). Soil nitrogen mineralization in plantations of *Juglans nigra* interplanted with *Elaeagnus umbellata* and *Alnus glutinosa*. *Plant and Soil* **118**: 33-42.

214. Pedersen, J.A. (1978). Naturally occurring quinols and quinones studied as semiquinones by electron spin resonance. *Phytochemistry* **17** : 775-778.

215. Peeples, E.A. (1988). Black walnut - bothersome beauty. *Country Journal (Mt. Morris, Il.)* **15**: 36-4(

216. Penuelas, J., Ribascarbo and Giles, L. (1996). Effects of allelochemicals on plant respiration and ox isotope fractionation by the alternative oxidase. *Journal of Chemical Ecology* **22** : 801-805.

217. Perlinger, J.A., Angst, W. and Schwazenbach, R.P. (1996). Kinetics of the reduction of hexachloethan juglone in solutions containing hydrogen. *Environmental Science and Technology* **30**: 2408-341

218. Perry, G.S. (1932). Some tree antagonisms. *Proceedings of the Pennsylvania Academy of Science* **6** :136-1·

219. Perry, S.F. (1967). Inhibition of respiration by juglone in *Phaseolus* and *Lycopersicon*. *Bulletin of Torrey Botanical Club* **94** : 26-30.

220. Phillips, H. (1820). *Pomarium Britannicum: An Historican and Botanical Account of Fruits Know Great Britain*. London : T. & J. Altman.

221. Piedrahita, O. (1984). Black walnut toxicity. *Factsheet*, Ministry of Agriculture and Food, Ontario (: 050) : 1-2.

222. Pinterne, K.E. and Terpo, A. (1977). The phenomenon of germination allelopathy in natural a experimental environment [Hungarian]. *Lippay Janos Tudomanyos Ulesszak Eloadasai* **8**(2 2153-2171.

223. Pirone, P.P. (1938). The detrimental effect of walnut on rhododendrons and other ornamentals. *Nurse Disease Notes* (N J Agric Expt Stn) **11**(4) : 1-4. Also in: *Northern Nut Growers Associatic Annual Report* **30** : 73-74 (1939).

224. Pliny the Elder. (1950, 1956). *Natural History* (Transl. H. Rackham, W.H.S. Jones) Volumes V and VI London: William Heinemann Ltd..

225. Ponder, F. (1987). Allelopathic interference of black walnut trees with nitrogen-fixing plants in mixe plantings. In: *Allelochemicals: Role in Agriculture and Forestry*. ACS Symposium Series 330 (Ed. G.R. Waller), pp. 195-204. Washington, D.C. : ACS.

226. Ponder, F., Tadros, M.G. and Tadros, S.H. (1987). Effects of juglone on growth and nodulation of hairy vetch. *Northern Nut Growers Association Annual Report* **78** : 46-50.

227. Ponder, F. and Tadros, S.H. (1985). Juglone concentration in soil beneath black walnut interplanted with nitrogen-fixing species. *Journal of Chemical Ecology* **11** : 937-942.

228. Prasad, R.B.N. and Gülz, P.-G. (1990). Surface waxes from leaves and fruits of walnut. *Phytochemistry* **29**: 2097-2099.

229. Prataviera, A.G., Kuniyuki, A.H. and Ryugo, K. (1983). Growth inhibitors in xylem exudates of Persian walnuts (*Juglans regia* L.) and their possible role in graft failure. *Journal of the American Society for Horticultural Science* **108** : 1043-1045

230. Rabotnov, T.A. (1977). The significance of the coevolution of organisms for the formation of phytocenoses [Russian]. *Byulleten' Moskovskogo Obshchestva Ispytatelei Prirody, Otdel Biologicheskii* **82**: 91-102.

231. Rabotnov, T.A. (1982). Importance of the evolutionary approach to the study of allelopathy. *Soviet Journal of Ecology* **12**: 127-130.

232. Radix, P., Seigle-Murandi, F, Benoit-Guyot, J.L. and Kriubok, S. (1994). Toxicity of walnut husk-washing waters. *Water Research* **26**: 1503-1506.

233. Ranade, S. and David, S.B. (1985). Quinones as plant-growth regulators. *Plant Growth Regulators* **3**: 3-13.

234. Randall, V.D. and Bragg, J.D. (1986). Effects of juglone (5'-hydroxy-1,4-naphthoquinone) on the algae *Anabaena flos-aquae*, *Nostoc commune* and *Scenedesmus acuminatus*. *Proceedings of the Arkansas Academy of Science* **40** : 52-55.

235. Rao, R.V.S. and Gujar, G.T. (1995). Toxicity of plumbagin and juglone to the eggs of the cotton stainer, *Dysdercus koenigii*. *Entomologia Experimentalis et Applicata* **77**: 189-192.

236. Reinking, O.A. (1943). Possible black walnut toxicity on tomato and cabbage. *Northern Nut Growers Association Annual Report* **34** : 56-58.

237. Reinking, O.A. (1947). Black walnut is deadly to tomatoes. *Flower Grower* **34** : 435-.

238. Renesse, D. von (1997). Experimentelle Untersuchungen und konceptionelle Überlegungen für ein screening-Verfahren des allelopathischen Potentials ausgewählter Baumarten (*Juglans* spp., *Eucalyptus camaldulensis*). *Beihefte zu der Tropenlandwirt, Deutsches Institut fur Tropische und Subtropische Landwirtschaft, Universität Gesamthochscule Kassel, Witzenhausen* **58**: 1-206.

239. Rettenmaier, H. (1985). *Untersuchungen zur Enzymatik des bakteriellen Juglonabbaues.* Inaugural Dissertation, Universität Hohenheim.

240. Rettenmaier, H., Kupas, U. and Lingens, F. (1983). Degradation of juglone by *Pseudomonas putida* J1. *FEMS Microbiology Letters* **19** : 193-195.

241. Rettenmaier, H. and Lingens, F. (1985). Purification and some properties of two isofunctional juglone hydoxylases from *Pseudomonas putida* J1. *Biological Chemistry Hoppe-Seyler* **366**: 637-646.

242. Reynolds, T. (1987). Comparative effects of alicyclic compounds and quinones on inhibition of lettuce fruit germination. *Annals of Botany* **60**: 215-223.

243. Rietveld, W.J. (1979). Ecological implications of allelopathy in forestry. In: *Regenerating Oaks in Upland Hardwood Forests. Proceedings 1979 John S. Wright Forestry Conference* (Eds. H.A. Holt and B.C. Fischer), pp. 90-112. West Lafayette : Purdue University.

244. Rietveld, W.J. (1981). The significance of allelopathy in black walnut cultural systems. *Northern Nut Growers Association Annual Report* **72** : 117-134. Also published in 1982: *USDA Forest Service General Technical Report* **NC 74** : 73-86.

245. Rietveld, W.J. (1983). Allelopathic effects of juglone on germination and growth of several herbaceous and woody species. *Journal of Chemical Ecology* **9** : 295-308.

246. Rietveld, W.J., Schlesinger, R.C. and Kessler, K.J. (1983). Allelopathic effects of black walnut on European black alder coplanted as a nurse species. *Journal of Chemical Ecology* **9** : 1119-1133.

247. Rink, G. and Van Sambeek, J.W. (1985). Variation among black walnut seedling families in resistance to competition and allelopathy. *Plant and Soil* **88** : 3-10.

248.* Robinson, F. (1998). *Plant friends of the black walnut.* American Horticultural Society.

249. Roshchina, V.D. (1973). Reducing power of woody plant leaf infusion and inhibition of Hill reaction with 2,6-dichlorophenol by them. In: *Fiziologo-Biokhimicheskie Osnovy Vzaimodeistviya Rastenii v Fitotsenozakh.* (Ed., A.M. Grodzinskii), **4**: 10-15. Kiev : Naukova Dumka.

250. Roshchina, V.V. and Roshchina, V.D. (1993). *The Excretory Function of Higher Plants.* Berlin: Springer Verlag.

251. Ross, M. (1996). Walnuts: a mixed blessing. *Flower and Garden* **40**(Aug Sept) : 53-54.

252. Rypma, R.B. (1989). Are black walnut trees poisonous to holly? *Holly Society Journal* **7**(3) : 4-14.

253. Saiz-Jimenez, C., Haider, K. and Martin, J.P. (1975). Anthroquinone and phenols as intermediates in the formation of dark-colored humic acid-like pigments by *Eurotium echinulatum. Soil Science Society of America Journal* **39**: 649-653.

254. Schlesinger, R.C. and Williams, R.D. (1984). Nurse crops improve black walnut growth. *Forest Ecology and Management* **9** : 235-243.

255. Schmidt, S.K. (1988). Degradation of juglone by soil bacteria. *Journal of Chemical Ecology* **14** : 1561-1571.

256. Schmidt, S.K. (1990). Ecological implications of the destruction of juglone (5-hydroxy-1,4-naphthoquinone) by soil bacteria. *Journal of Chemical Ecology* **16** : 3547-3549.

257. Schmidt, S.K. and R. E. Ley (1999). Microbial competition and soil structure limit the expression of allelochemicals in nature. In: *Principles and Practices in Plant Ecology: Allelochemical Interactions* (Ed., Inderjit, K.M.M. Dakshini and C.L. Foy). Boca Raton : CRC Press (in press).

258. Schneiderhan, F.J. (1926). Apple disease studies in northern Virginia. *Virginia Agricultural Experiment Station Bulletin* **245** : 1-35.

259. Schneiderhan, F.J. (1927a). The black walnut (*Juglans nigra* L.) as a cause of the death of apple trees. *Phytopathology* **17** : 529-540.

260. Schneiderhan, F.J. (1927b). Recent developments in the control of fruit diseases. *Proceedings of the Virginia State Horticultural Society* **31** : 145-157.

261. Schopfer, W.H. and Keller, V. (1951). Action of vitamin K3 and nicotinic acid on the green and colourless forms of *Euglena gracilis*. *Bulletin de la Société de Chimie Biologique* **33**: 1253-1260.

262. Schreiner, E.J. (1949). Can black walnut poison pines? *Morris Arboretum Bulletin* **4** : 94-96.

263 Schreiner, E.J. (1950). Can black walnut poison pines? *Shade Tree* **23**(1): 2.

264. Schreiner, O. and Reed, H.S. (1907a). The production of deleterious excretions by roots. *Bulletin of the Torrey Botanical Club* **34** : 279-303.

265. Schreiner, O. and Reed, H.S. (1907b). Some factors influencing soil fertility. *US Department Agriculture Bureau of Soils Bulletin* **40** : 1-40.

266. Schultz, R.C. and Kormanik, P.P. (1982). Vesicular-arbuscular mycorrhiza and soil fertility influence mineral concentrations in seedlings of eight hardwood species. *Canadian Journal of Forest Research* **12**: 829-834.

267. Segura-Aguilar, J., Hakman, I. and Rydström, J. (1992). The effect of 5OH-1,4-naphthoquinone on Norway spruce seeds during germination. *Plant Physiology* **100** : 1955-1961.

268. Sherman, R.R. (1971). *An Ecological Evaluation of the Allelopathic Influence of Juglans nigra on Lycopersicon esculentum*. East Lansing : M.Sc. thesis, Michigan State University.

269. Shilling, D.G. and Yoshikawa, F. (1987). A rapid seedling bioassay for the study of allelopathy. In: *Allelochemicals: Role in Agriculture and Forestry* (Ed., G.R. Waller), pp. 334-342. Washington, D.C. : ACS.

270. Sidhu, G.S., Pardhasaradhi, M. and Babu, M.H. (1975). Isolation of tris-juglone from *Juglans regia* bark. *Indian Journal of Chemistry* **13**: 749

271.* Silva, E.M. (1997). Plant against plant. *The Virginia Gardener Newsletter* **8**(4).

272. Smith, J.R. (1941). One plant's meat is another plant's poison. *Northern Nut Growers Association Annual Report* **32** : 28-31:.

273. Smith, R.M. (1942). Some effects of black locusts and black walnuts on southeastern Ohio pastures. *Soil Science* **53** : 385-398.

274. Soderquist, C.J. (1973). Juglone and allelopathy. *Journal of Chemical Education* **50** : 782-783.

275. Sokolov, I.N., Chekhova, A.E., Ellseev, Y.T., Nilov, G.I. and Shcherbanovskii, L.R. (1972). Study of antimicrobial activity of certain naphthoquinones [Russian]. *Prikladnaya Biokhimiya I Mikrobiologiya* **8** : 261-263.

276. Spencer, G.F., Tjarks, L.W., England, R.E. and Seest, E.P. (1986). The effect of naturally occurring naphthoquinones on velvetleaf (*Abutilon theophrasti*) germination. *Journal of Natural Products (Lloydia)* **49** : 530-533.

277. Spiegl, P. and Chirikdjian, J.J. (1972). Flavonoid distribution in *Juglans regia*. *Pharmazie* **24**: 780-781.

278. Steffen, K. and Peschel, H. (1975). Chemische Konsitution und antifungale Wirkung von 1,4-naphthochinonen, deren biosynthetischer Zwischenprodukte und chemisch verwendter Stoffe. *Planta Medica* **27** : 201-212.

279. Steinberg, J. (1959a). *Hassiche Lehr- und Forschungsanstalt für Wein-, Obst- und Gartenbau Geisenheim (Rheingau). Berichte für das Rechnungsjahr 1957 58.*

280. Steinberg, J. (1959b). *Hassiche Lehr- und Forschunganstalt für Wein-, Obst- und Gartenbau Geisenheim (Rhinegau). Berichte für Rechnungsjahr 1958/59.*

281. Stickney, J.S. and Hoy, P.R. (1881). Discussion. *Transactions of the Wisconsin State Horticultural Society* **11** : 166-167.

282. Stierle, A.A., Upadhyay, R., Hershenhorn, J., Strobel, G.A. and Molin, A.G. (1991). The phytotoxins of *Mycosphaerella fijiensis*, the causative agent of Black Sigatoka disease of bananas and plantains. *Experientia* (Basel) **47**: 853-859.

283. Stipanovic,R.D. and Bell, A.A. (1977). Phenaketide metabolites of *Verticillium dahliae*. 2. Accumulation of naphthol derivatives by aberrant-melanin mutant brm-2. *Mycologia* **69**: 164-172.

284. Strong, M.C. (1944). Walnut wilt of tomato. *Michigan Quarterly Bulletin* **26** : 194-195.

285. Sublett, K.L. (1977). Juglone - comparison of natural and synthetic products. *Journal of Chemical Education* **54** : 156.

286. Summers, D.A. and Lussenhop, J. (1976). The response of soil arthropods to canopies of black walnut. *Pedobiologia* **16**: 389-395.

287. Talapatra, S.K., Karmacharya, B., De, S.C. and Talapatra,, B. (1988). (-)-regiolone, an $\alpha$-tatralone from *Juglans regia*: structure, stereochemistry and conformation. *Phytochemistry* **27**: 3929-3232.

288. Talley, S.M., Lawton, R.O. and Setzer, W.N. (1996). Host preferences of *Rhus radicans* (Anacardiaceae) in a southern deciduous hardwood forest. *Ecology* 77 : 1271-1276.

289. Taverna, G. (1964). The activity of 5-oxy-naphthoquinone in the metabolism of the Juglandaceae. II. *Annali della Facolta di Scienze Agrarie Universita degli Studi di Napoli Portici* **29 :** 379-388.

290. Taverna, G. (1968). The activity of 5-oxy-naphthoquinone in the metabolism of the Juglandaceae. III. *Annali della Facolta di Scienze Agrarie Universita degli Studi di Napoli Portici*. Ser. **43** : 292-298.

291. Tekintas, E., Tanrisever, A. and Gunver, G. (1988). Xylem sap and its juglone content in walnut (*Juglans regia* L.) saplings [Turkish]. *Ege Universitesi Ziraat Fakultesi Dergisi* **25**(3) : 1-11.

292. Tekintas, E., Tanrisever, A. and Mendilcioglu, K. (1988). Isolation and annual variation of juglone in walnuts (*Juglans regia* L.) [Turkish]. *Ege Universitesi Ziraat Fakultesi Dergisi* **25**(2) : 215-225.

293. Tekintas, E., Tanrisever, A., Mendilcioglu, K. and Inal, A. (1988). Effect of juglone on seed germination [Turkish]. *Ege Universitesi Ziraat Fakultesi Dergisi* **25**(2) : 203-213.

294. Thakur, V.C. and Bhardwaj, S.D. (1992). Allelopathic effect of tree leaf extracts on germination of wheat and maize. *Seed Research* **20**: 153-154

295. Thiboldeaux, R.L., Lindroth, R.L. and Tracy, J.W. (1994). Differential toxicity of juglone (5-hydroxy-1,4-naphthoquinone) and relared naphthoquinones to saturniid moths. *Journal of Chemical Ecology* **20**: 1631-1641.

296. Thijs, H., Shann, J.R. and Weidenhamer, J.D. (1994). The effect of phytotoxins on competitive outcome in a model system. *Ecology* **75**: 1959-1964.

297. Thomson, R.H. (1971). *Natually Occurring Quinones*. Second Edition. New York: Academic Press.

298. True, R.G. and Lowe, J.E. (1978). Black walnut shavings as a cause of acute laminitis. *Proceedings of the American Association of Equine Practitioners* **24**: 511-515.

299. Tyzh, R.M., Anikina, S.A. and Mel'nik, O.F. (1983). Allelopathic effect of several types of trees on the growth and biochemical features of Persian walnut seedlings [Russian]. In: *Rol' Toksinov Rastitel'nogo i Mikrobial'nogo Proiskhozhdeniya v Allelopatii* (Eds., A.M. Grodzinskii, G.P. Bogdan, E.A. Golovko, N.N. Dzyubenko, V.P. Ivanov, N.A. Kokhno, P.A. Moroz, N.I. Prutenskaya, I.N. Rakhteenko and K.M. Khailov), pp. 133-137. Kiev: Naukova Dumka

300. USDA (1948). Test clears walnut's reputation. Clip Sheet 2375-48 :.

301. Uygur, F.N. and Iskenderoglu, S.N. (1997). Allelopathic and bioherbicide effects of plant extracts on germination of some weed species [Turkish]. *Turkish Journal of Agriculture and Forestry* **21** : 177-180.

302. Vance, L.J. (1900). Walnut lore. *Lippincotts Monthly Magazine* **59** : 142-144.

303. Van Sambeek, J. (1995). Walnut hotline - pine and walnut mixed plantings. *Walnut Council Maryland Chapter Newsletter* **2**(1): 2.

304. Van Sambeek, J.W., Kobe, J.M. and Fralish, J.S. (1997). Interference with shoot growth and flowering of dittany (*Cunila origanoides* (L.) Britton) by hardwood species. In: *Proceedings of the 11th Central Hardwood Forest Conference*, pp. 294-303. USDA Forest Service General Technical Report NC-188.

305. Van Sambeek, J.W. and Rietveld, W.J. (1981). Seeding forage legumes in black walnut plantations. *Walnut Council Bulletin* **8**(1): 6-8.

306. Van Sambeek, J.W. and Rietveld, W.J. (1982). Leguminous cover crops can suppress weeds and accelerate growth of black walnut seedlings in intensively cultured plantations. In: *Proceedings of the 4th Central Hardwood Forest Conference* (Ed. R.N. Muller), pp. 229-243. Lexington.

307. Van Sambeek, J.W., Schlesinger, R.C., Ponder, F. and Rietveld, W.J. (1985). Actinorhizal species as nurse crops for black walnut. In: *Proceedings of the 5th Central Hardwood Forest Conference* (Ed. J.O. Dawson and K.A. Majerus), pp. 257-263. SAF Publication 85-05.

308. Varga, Z., Bene, L., Damjanovic, S. and Gaspar, R. (1996). The effect of juglone on the membrane potential and whole-cell K+ currents of human lymphocytes. *Biochemical and Biophysical Research Communications* **218**: 828-832.

309. Varro (1912). *Varro on Farming* [De Rerum Rusticarum]. London : C. Bell and Sons.

310. Verona, O. and Fagioli, M. (1952). Sulla presunta azione fungicida dello juglone. *Nuovo Giornale Botanico Italiano n.s.* **59**: 438-440

311. Vogel, C.S. and Dawson, J.O. (1985). Effect of juglone on growth *in vitro* of *Frankia* isolates and nodulation of *Alnus glutinosa* in soil. *Plant and Soil* **87** : 78-89.

312. Vogel, C.S. and Dawson, J.O. (1986). *In vitro* growth of five *Frankia* isolates in the presence of four phenolic acids and juglone. *Soil Biology and Biochemistry* **18** : 227-232.

313. Walker, L.C. (1990). *Forests: a naturalist's guide to trees and forest ecology*. New York : John Wiley & Sons.

314. Wang, K.-L. (1971). *Physiological Effects of Juglone on Higher Plants*. Ph.D. thesis, Kansas State University.

315. Weidenhamer, J.D., Hartnett, D.C. and Romeo, J.T. (1989). Density dependent phytotoxicity: distinguishing resource competition and allelopathic interference in plants. *Journal of Applied Ecology* **26** : 613-624.

316. Weidenhamer, J.D., Macias, F.A., Fischer, N.H. and Williamson, G.B. (1993). Just how insoluble are monoterpenes. *Journal of Chemical Ecology* **19** : 1799-1807.

317. Weidenhamer, J.D., Morton, T.C. and Romeo, J.T. (1987). Solution volume and seed number: often overlooked factors in allelopathic bioassays. *Journal of Chemical Ecology* **13** : 1481-1492.

318. Weissenberg, M, Meisner, J., Klein, M., Schaeffer, I, Eliyahu, M., Schmutterer, H. and Ascher, K.R.S. (1997). Effect of substituent and ring changes in naturally occurring naphthoquinones on the feeding responses of larvae of the Mexican bean beetle *Epilachna varivestis*. *Journal of Chemical Ecology* **23**: 3-18.

319. Westfall, B.A., Russell, R.L. and Auyong, T.K. (1961). Depressant agent from walnut hulls. *Science* **134** : 1617.

320. Wheeler, A.S. and Scott, J.W. (1919). Halogenation of juglone: a new type of naphthalene dyes. *Journal of the American Chemical Society* **41**: 833-841.

321. Wiant, H.V. and Ramirez, M.A. (1974). Don't plant white pine near walnut!. *Tree Planters' Notes* **25**(4) : 30.

322. Wieditz, C. and Hesse, M. (1990). Allelopathie - wie Pflanzen einander chemisch beeinflussen. *Praxis der Naturwissenschaftlich Biologie* **39**(4) : 27-31.

323. Wilkinson, J.F. (1948). The toxic effect of walnut trees on apple trees, and other plants. *Iowa State Horticultural Society Proceedings* **82** : 134-137.

324. Williams, R.D. and Hoagland, R.E. (1982). The effects of naturally occurring phenolic compounds on seed germination. *Weed Science* **30** : 206-212.

325. Williamson, G.B. and Weidenhamer, J.D. (1990). Bacterial degradation of juglone: evidence against allelopathy? *Journal of Chemical Ecology* **16** : 1739-1742.

326. Willis, R.J. (1985). The historical bases of the concept of allelopathy. *Journal of the History of Biology* **18**: 71-102.

327. Willis, R.J. (1996). Allelopathy in *Eucalyptus*: Australian studies. In: *Allelopathy: Field Observations and Methodology*. (Eds., S.S. Narwal and P. Tauro), pp. 41-64. Jodhpur : Scientific Publishers.

328. Willis, R.J. (1999). Australian studies on *Eucalyptus*: a review. In: *Principles and Practices in Plant Ecology: Allelochemical Interactions* (Ed.: Inderjit, K.M.M. Dakshini and C.L. Foy). Boca Raton: CRC Press (in press).

329. Wood, B.W., Gottwald, T.R. and Reilly, C.L. (1988). Pecan phyllosphere chemicals influence germination of pecan scab conidia. *Journal of the American Society for Horticultural Science* **113**: 616-619.

330. Worlidge, J. (1677). *Systema Horti-culturae, or the Art of Gardening*. London : T. Burrel and W. Hensman.

331. Zatyko, J. (1964). Investigations on root formation in walnut [Hungarian]. *Kiserletügyi Közlemények Section C* **57**(2) : 35-42.

332. Zitzer, S.F. and Dawson, J.O. (1989). Seasonal changes in nodule nitrogenase activity of *Alnus glutinosa* and *Eleagnus angustifolia*. *Tree Physiology* **5** : 185-194.


* Entries followed with an asterisk have been sourced from the Internet.