Database for Estimating Tree Responses of Walnut and Other Hardwoods to Ground Cover Management Practices

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Abstract

The ground cover in plantings of walnut and other hardwoods can substantially affect tree growth and seed production. The number of alternative ground covers that have been suggested for establishment in tree plantings far exceeds the number that have already been tested with walnut and other temperate hardwoods. Knowing how other hardwood species respond to ground covers and which have responses statistically similar to that for walnut would greatly expand our knowledge base for making predictions and recommendations for ground covers in hardwood plantings. Data from over 110 reports of which nearly half included walnut species were compiled into a spreadsheet. The spreadsheet database compares multi-year growth and nut or fruit production of trees growing in different ground covers to that of trees in plots either with little or no management of the weedy vegetation or vegetation-free plots maintained through cultivation, herbicides, or mulches. For most hardwoods with moderate growth rates, growth as a percentage of growth in vegetation-free treatments is similar to the reduction observed for walnut saplings and pole-sized trees managed with forage legumes and grasses. In general, forage grasses have a greater impact on tree growth than do forage legumes. Although frequently used as a method of competition control, mowing does not alleviate the negative impacts of most ground covers on tree growth. Additional studies will likely need to be done before predictions similar to those for growth can be made on the effect of ground covers on fruit or nut production.

INTRODUCTION

Maximum tree growth and nut production of black walnut (*Juglans nigra* L.), butternut (*Juglans cinerea* L.), and Persian (English) walnut (*Juglans regia* L.) are expected to occur on well-drained, fertile sites maintained free of vegetation (Van Sambeek, 1989; Ramos, 1998; Alley et al., 1999). A vegetation-free approach to orchard management has significant environmental consequences including substantial soil erosion, soil compaction, wider fluctuations in soil temperature, and significant losses of soil moisture through surface evaporation (Ingels et al., 1998; Willoughby and McDonald, 1999). Benefits of orchard management with a ground cover include shading of soil to reduce surface evaporation, a turf to support equipment for maintenance and harvesting, and fixation of atmospheric nitrogen if it includes legumes (Ramos, 1998). Several studies have documented that an established stand of tall fescue (*Festuca arundinacea* Schreb.) can severely impact growth and nut production of black walnut and other hardwoods (Holt and Voeller, 1975; Schlesinger and Van Sambeek, 1986; Van Sambeek and McBride 1991; Alley et al., 1999). In contrast, the management of herbaceous legumes between trees can result in improved growth and fruit yields when compared to check treatments comprised of a mixed population of seedbank grasses and forbs (Haines et al., 1978; Van Sambeek et al., 1986; Van Sambeek, 2003).

The objectives of this work are to describe a spreadsheet database being created using results from various publications and reports that can be used to statistically

evaluate tree responses to different ground covers. Emphasis initially has been placed on compiling information from publications that have included walnut species along with other species. A secondary objective is to compare growth responses to common control treatments to determine what other tree species have responses similar to walnut species to broaden the inference basis for making recommendations on impact of different management practices.

MATERIALS AND METHODS

A key word search of the horticulture, arboriculture, and forestry literature and the literature cited within candidate publications produced more than 50 publications reporting on impact of ground covers on black walnut for one or more measures of tree growth or fruit production (Van Sambeek and Garrett, 2004). Publications were systematically analyzed to determine if reported studies included at least one nut tree or hardwood species with moderate growth rates, one or more treatments that could serve as a vegetation-free control or a resident vegetation control (non-managed plots usually with a succession of mixed forbs and grasses from a pre-existing seedbank), and response measurements over two or more years to minimize including reports with negative growth increment or growth under unique weather events.

For those reports that met these criteria, information was extracted from the text, figures, and tables for each publication and recorded on a worksheet to facilitate entering information into an Excel 3.0 spreadsheet (Microsoft Corporation). The spreadsheet is structured with the first row containing unique variable names followed by rows with information from each report that includes source, site information, and responses of each tree species to various combinations of control and experimental ground cover treatments. To the extent possible letter codes are standardized as described below to facilitate eventual sorting of variables and conducting statistical analyses. The current spreadsheet database is designed to contain the following information:

One column is coded for the publication or report that is the original source of the information by using the first letter of the last name of up to four authors followed by year published, i.e., this paper will probably be coded as V2009. The source code is also used to link to a separate database that has a full ANSI citation to the original publication or report.

Four columns are coded to the study location and soils information. Two columns are used for the first eight letters of the county or nearest town and the two-letter state or three-letter country abbreviations. Two columns are coded to the first eight letters of the soil series name and a four-letter code is used to describe the predominant soil type, e.g., SILM for silty loam and SALM for sandy loam.

Three columns are used to identify what tree species are included in the publication or report. One column is used for the common name and another column is coded using the first three letters of genus and the species name, i.e., JUGNIG for black walnut and JUGREG for Persian walnut. The third column places tree species within one of the following broad categories: walnut species (JGLNS), pecan and hickory (CARYA), oak (QURCS), ash (FRXNS), actinorhizal or nodulated tree legumes (N-FIX), fruit (FRUIT), short-rotation (BIOMS), other hardwoods (HRDWD), pines (PINUS), or other conifers (CONFR). Short-rotation species include most fast-growing trees, e.g., hybrid poplar (*Populus* hybrids) and silver maple (*Acer saccharinum* L.), that are expected to rapidly develop a closed canopy and quickly shade out the competing herbaceous ground cover.

Three columns are used to indicate the year that seed of each tree species was germinated in the nursery or direct seeded at the study site, the year the last fall measurements were made before the spring establishment of any ground cover treatments, and the year for last reported fall measurements that are reported in the publication.

Two columns are used to provide information on growing space per tree and percentage of that area covered by the experimental treatment. For closely-spaced trees, growing space (m^2) is calculated as distance between tree rows times spacing within

rows. For widely-spaced trees the growing space is assumed to be twice the crown area at the end of the evaluation period and estimated from the diameter at breast height in cm as $6 \times (dbh + 0.5)^2$. The second column estimates percentage of growing space that is being managed under the experimental treatment (excludes areas with a different ground cover than the experimental treatment).

Three columns are used to report what measurements were made on the trees and their units. The following standard codes are used: height (HT), stem diameter (DAH or DBH), basal area (BA), trunk cross sectional area (TCSA), volume (VOLM), mass (MASS), foliar N (FOLRN), and fruit or nut yield (YIELD). Foliar nitrogen is included as a growth variable because half the foliage nitrogen in leaves is normally associated with the photosynthetic structures and enzymes and presumably positively correlated with tree growth.

Two columns are used to code the control treatment as either resident vegetation (RSDNT) or vegetation-free treatments (VEGFR) and to give a short physical description of the control treatment(s). Resident vegetation is used to describe an unmanaged succession of grasses and forbs, i.e., weeds, typically originating from the existing seed-bank (Ingels et al., 1999). The vegetation-free control treatment can be a single treatment or a combination of two or more treatments that result in plots that are more than 50% free of ground cover vegetation.

Three columns are used to give a short description of the experimental treatment and to code both for an experimental treatment group and for the specific treatment. Codes for experimental treatment group currently include vegetation-free (VEGFR), mixed grasses and forbs from seedbank (RSDNT), cut or mowed only (MOWED), grasses (GRASS), herbaceous legumes (LEGUM), non-leguminous forbs (FORBS), application of nitrogen-containing fertilizers (FRTLZ), irrigation (IRRIG), mechanical weed control (TILLG), application of herbicides (HRBCD), use of organic mulches (ORGAN) or synthetic or inorganic mulches (SYNTH), interplanted actinorhizal and tree legumes (N-FIX), and interplanted other trees and shrubs (NURSE). Treatments within the groups are usually coded with a six letter code for the genus species of the ground cover, i.e., FESARU for tall fescue and TRIREP for white clover (*Trifolium repens*), or for a physical description of the non-plant treatments, i.e., GLYPHO for glyphosate applications and BLKNPM for black, non-porous polyethylene mulch.

Four columns are used to list the pre-treatment and post-treatment values for the control treatment and the experimental treatments for each measurement and tree species combination. When a study had more than one vegetation-free treatment, the pre-and post-treatment values for each treatment were averaged to determine values for the vegetation-free control. Unless reported in the publication, one-year-old hardwood planting stock are assumed to have pre-treatment values of 40 cm (15 inches) for stem height and 6 mm (0.25 inches) for basal stem diameter when planted. Grafted trees on 2-year-old rootstocks are assumed to be twice this size. Basal stem diameter (DAH) is assumed to be 2 cm larger than diameter at breast height (DBH).

Three columns are used to calculate annual growth or yields and to calculate growth response as a percentage of either the resident vegetation or vegetation-free control. Annual growth is the difference between the pre-treatment and post-treatment measurements divided by the difference between year of last reported measurement and year before ground cover treatments were initiated. Growth or yield as a percentage of control is annual increment for experimental treatment divided by annual increment for control treatment. If either annual growth increment is negative, then percentage is changed to a missing value recognized as such by the software to be used for statistical analyses.

Two columns are used to record if the original report or publication indicated there were significant differences between the experimental and control treatments. One column contains reported or estimated least significant differences for original measurements. Second column is coded as 1 or 0 where 1 indicates original paper reported statistically significant differences ($p \leq 0.05$) existed between the experimental and control treatments.

For statistical analyses of tree responses to the different ground cover treatments, columns containing information on tree class and species, ground cover class and treatment, control treatment (resident vegetation or vegetation-free), and response as percent of control are extracted from the database and imported into SAS Version 9.2 software (SAS, Cary, NC). SAS Enterprise Guide is used to identify outliers and determine whether responses as percent of control are normally distributed. Normally distributed responses are subjected to ANOVA using PROC MIXED and means separation using the PDMIX800 software.

RESULTS AND DISCUSSION

Use of a spreadsheet database has proven to be a highly effective method for compiling information on the response of trees to various ground cover management practices. Options for data sorting permit easy grouping by tree species or management practices. The addition of several new variables from an earlier version used by Van Sambeek and Garrett (2004) now provides information on tree age, soil properties, and statistical significance of responses based on the original research. Columns with coded information and tree responses are easily consolidated into one section to facilitate importing data into statistical software for ANOVA and means separation of main effects and interactions (Table 1). As additional information is compiled in the future, this information can easily be imported into already written programs designed to complete data manipulation, ANOVA, and means separation procedures. Although growth responses in current database are best fitted to a normal distribution, newer software allows for statistical analyses of normally and non-normally distributed percentage data without transformation (PROC GLIMMIX, SAS, Cary, NC).

The database currently has over 3500 entries from over 110 reports and publications compiling information on the growth response of different tree species groups to different ground cover management practices. Practices that include using mulches and application of nitrogen fertilizers to vegetation-free areas within the rooting zone can significantly increase walnut growth compared to tree growth maintained vegetation-free through use of tillage or herbicides (Table 1). Inclusion of vegetation on more than half the growing space typically results in growth reductions of walnut when compared to trees with more than half the growing space largely free of competing vegetation. Walnut growth on plots when managed with resident vegetation or a succession of mixed grasses and forbs from an existing seedbank is typically only 55 to 60% of that in vegetation-free plots. Growth reductions can be even greater when resident vegetation is mowed one or more times during the growing season. Although growth of walnut trees in plots seeded to herbaceous legumes is greater than growth in plots seeded to grasses, neither is statistically different from walnut growth in plots managed with resident vegetation.

Analysis of variance for growth response by management practices and tree species groupings yields a highly significant interaction (Table 1). Growth responses of coniferous species are the most dissimilar to that of walnut showing significantly different growth responses when trees are managed with resident vegetation, grass sods, legume cover crops, mowed, or mulched. In contrast, few differences in growth responses exist between the *Fraxinus* species group and the *Juglans* species group except for practices that include mowing or herbicides for weed control. These results indicate responses reported in most studies using either walnut or ash species could be used to make highly reliable inferences about how walnut would respond to living mulches or cover crops of various grasses or legumes that have not been tested with walnut species. Preliminary results suggest the *Quercus* species are less affected by grass sods, legume cover crops, and mulching than are the *Juglans* species and growth responses of *Quercus* species probably should not be included in analyses designed to predict response of walnut trees to most management practices.

Growth of *Juglans* and *Fraxinus* species in response to grass sods can range from as little as 40% to as much as 80% of the growth for the same species growing in

vegetation-free management practices (Fig. 1). Predicted walnut growth with grass sods is not statistically different from tree growth with resident vegetation although there is a trend for most grass species to be less competitive than weedy vegetation. Tall fescue is the notable exception such that in 67% of hardwood plantings tree growth will be only 16 to 66% of growth had the planting been managed free of vegetation.

Herbaceous legumes managed as cover crops or living mulches in walnut plantings are expected to reduce tree growth to as much as 40% to as little as 80% of the growth expected in vegetation-free walnut plantings (Fig. 2). Only alfalfa (*Medicago sativa*) is more competitive than resident vegetation or the other legume species that have been tested in tree plantings.

The database was initiated in part to answer questions on how ground cover management practices influence flower and nut production of *Juglans* species. Most of the entries for flower and fruit production in the current database involve fruit tree responses to the various ground cover management practices. Of the responses for the walnut species, most have evaluated what is the best time during the growing season and how much nitrogen to apply to increase nut production (Jones et al., 1995; Van Sambeek et al., 1998; Gray and Garrett, 1999). To increase the usefulness of the database as a tool for predicting walnut responses for nut production, future efforts need to concentrate on compiling more of the existing information on nut and fruit production and monitoring nut production in on-going screening trials with different ground cover treatments.

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Tables

Table 1. Responses of different tree groups to various ground cover treatments as a percentage of responses in vegetation-free treatments and probability responses are similar to that of the walnut species.

Ground cover management practices	Walnut response as percentage of control[y]	Response as percentage of vegetation-free treatments and probability[z] of tree responses being similar to walnut group			
				Other	
		Quercus sp.	*Fraxinus* sp.	Hardwood sp.	Conifer sp.
Unmanaged weeds	54±27(42)	62±39(51)$^{n.s.}$	58±24(70)$^{n.s.}$	64±24(70)$^{n.s.}$	88±32(30)***
Mowing only	44±29(20)	49±28(26)$^{n.s.}$	82±3(4)*	66±20(40)**	93±15(4)*
Grass cover crops	50±28(109)	81±43(32)***	54±25(8)$^{n.s.}$	69±31(143)***	65±30(27)*
Legume cover crops	63±24(154)	80±61(23)**	50±25(5)$^{n.s.}$	68±23(106)$^{n.s.}$	74±24(61)**
Tillage practices	97±15(18)	72±21(5)$^{n.s.}$	117±23(7)$^{n.s.}$	109±25(23)$^{n.s.}$	92±5(3)$^{n.s.}$
Herbicide application	96±20(41)	98±19(30)$^{n.s.}$	79±27(21)*	92±24(53)$^{n.s.}$	107±11(9)$^{n.s.}$
Nitrogen fertilizers	116±19(42)	118±33(39)$^{n.s.}$	122±17(10)$^{n.s.}$	140±37(39)***	109±18(5)$^{n.s.}$
Synthetic mulches	144±54(15)	107±26(15)***	129±44(11)$^{n.s.}$	99±23(45)***	99±11(6)***
Organic mulches	143±54(21)	119±39(38)**	168±43(3)$^{n.s.}$	116±26(21)**	94±16(5)***

[z] n.s., not significant ($p>0.05$); * significant at $p<0.05$; ** significant at $p<0.01$; and *** significant at $p<0.001$ based on Tukey-Kramer least square means t-tests.

[y] Response mean ± standard deviation (number of responses) as percent of response in vegetation-free treatments.

Figures

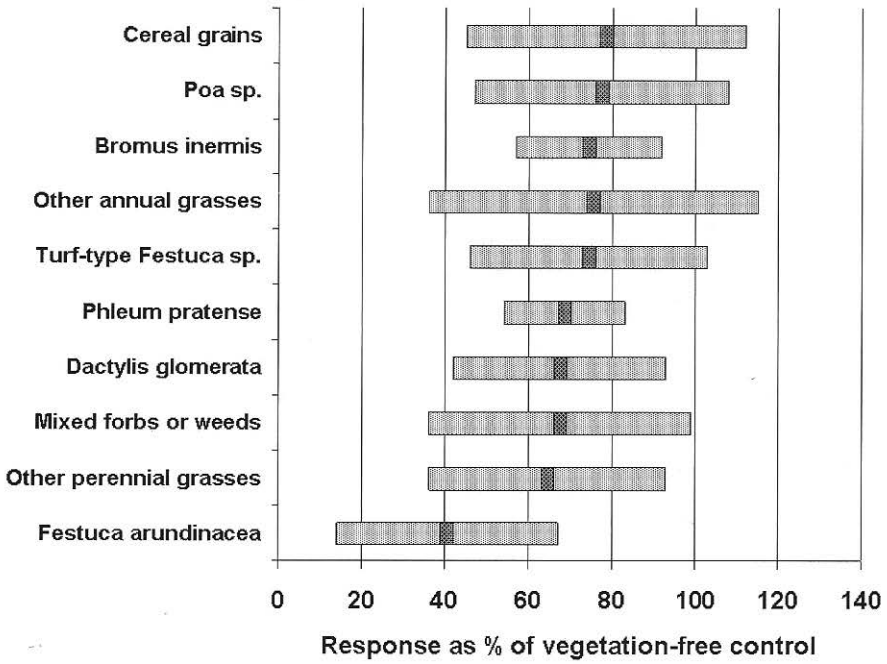


Fig. 1. Mean growth response (dark bands) and standard deviations for walnut and other hardwoods to grass cover crops or living mulches as a percentage of growth response in adjacent vegetation-free plots.

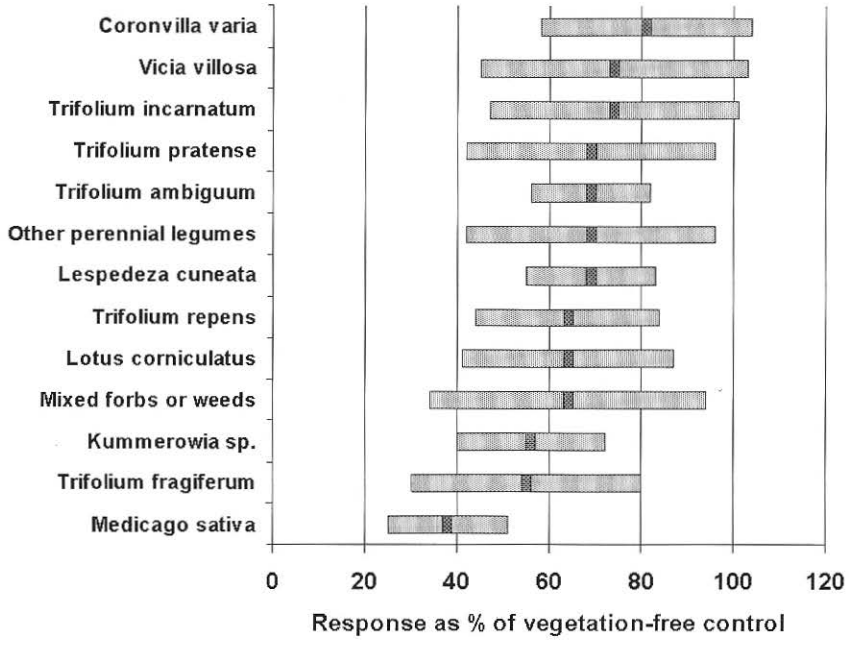
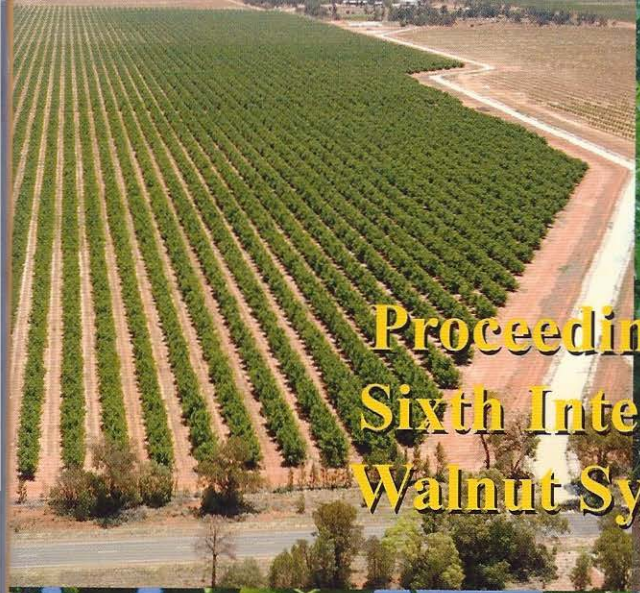
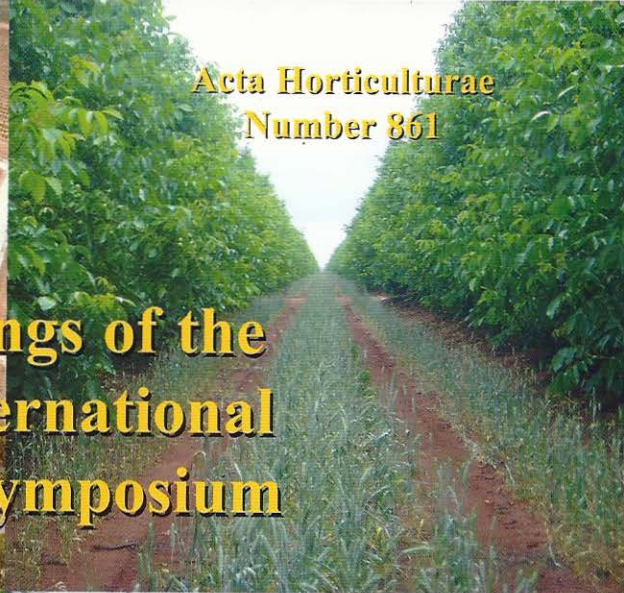


Fig. 2. Mean growth response (dark bands) and standard deviation for walnut and other hardwoods to leguminous cover crops or living mulches as a percentage of growth response in adjacent vegetation-free plots.





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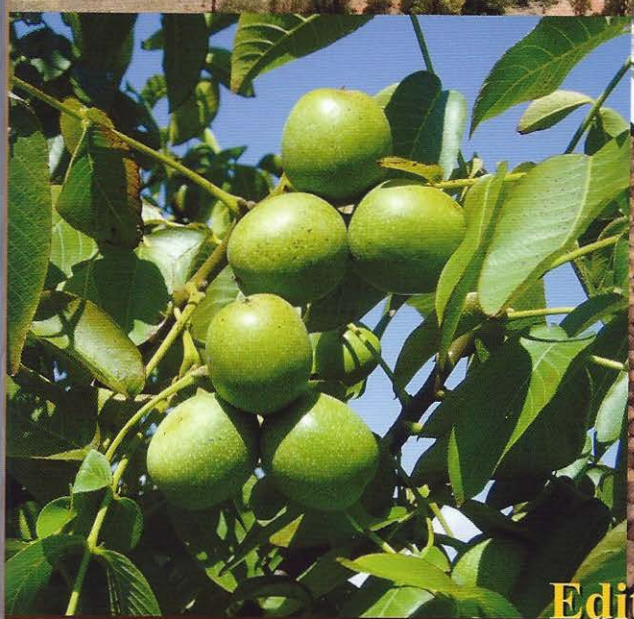

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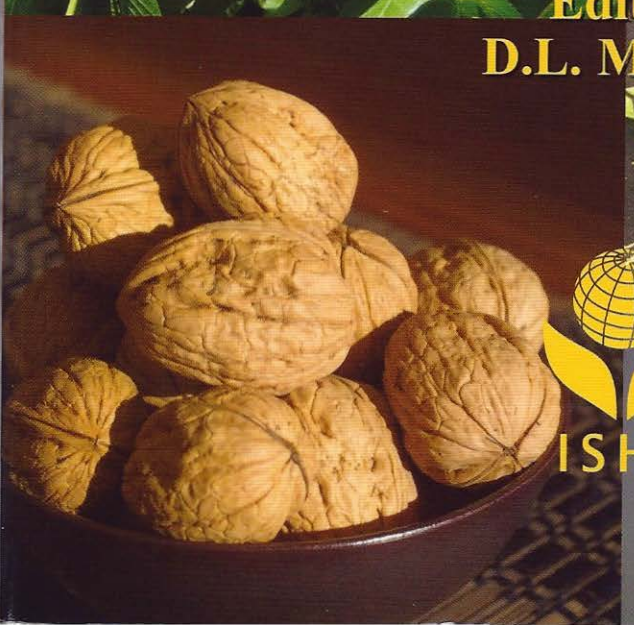

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