

## THE TERPENOID CHEMISTRY OF SUNFLOWERS (*HELIANTHUS*)

Jonathan Gershenzon\*, Nobuo Ohno\*\* and Tom J. Mabry\*

\*Department of Botany  
The University of Texas at Austin  
Austin, TX 787112, USA

\*\*Sumitomo Chemical Company, Ltd.  
Institute for Biological Science  
4-2-1 Takatsukasa, Takarazuka  
Hyogo 665, JAPAN

**ABSTRACT.** The increasing agricultural importance of cultivated sunflower (*Helianthus annuus*) has prompted a growing interest in the chemistry of the entire genus, a group of approximately 50 species native to North America. Sunflowers have proved to be especially rich sources of several classes of terpenoids, including sesquiterpene lactones, diterpenes and triterpenes, all of which are typical secondary metabolites of the family Compositae. Three different types of sesquiterpene lactones have been found, germacranolides, including both germacrolides and heliangolides, eudesmanolides and guaianolides. Diterpenes isolated consist mostly of carboxylic acids with labdane, kaurane and trachylobane skeletons. A substantial number of sterols, triterpene alcohols and saponins have also been found. The terpenoid chemistry of *Helianthus* conforms well to what might be expected for a genus of the Compositae, though at this stage of investigation, it is too early to detect any clear systematic trends within the genus.

The acreage devoted to sunflower cultivation has greatly expanded in the last few years, particularly in the United States. However, severe insect problems limit further increases. Attention is focusing on sesquiterpene lactones and diterpenes as possible sources of resistance to some of the most serious pests.

**RESUMEN.** La creciente importancia del girasol (*Helianthus annuus*) en la agricultura ha influido en el interés de establecer la química del género completo que incluye unas 50 especies nativas a Norte América. Los girasoles han demostrado ser fuentes muy abundantes de varias clases de terpenoides incluyendo lactonas sesquiterpénicas, diterpenos y triterpenos que son metabolitos secundarios típicos de la familia Compositae. Se han aislado tres tipos diferentes de lactonas sesquiterpénicas: germacranólidos, incluyendo germacrólidos y heliangólicos como así también eudesmanólidos y guaianólidos. Los diterpenos aislados consisten principalmente en ácidos carboxílicos con esqueletos de labdano, kaureno y trachylobano. También fue aislado un número considerable de esteroides, alcoholes triterpénicos y saponinas. La química de los terpenoides de *Helianthus* está de acuerdo con la que se puede esperar de un género perteneciente a la Familia Compositae, aunque en el presente estado de investigación todavía es muy prematuro detectar alguna organización sistemática en el género.

El área dedicada al cultivo de los girasoles se ha expandido enormemente en los últimos años, en particular en los EEUU. De todo modos, hay problemas muy severos con los insectos que limitan aún más su expansión. Se está prestando atención particular a las lactonas sesquiterpénicas y a los diterpenos como fuentes posibles de resistencia a algunas de las plagas más dañinas.

### INTRODUCTION

*Helianthus* L. (Tribe Heliantheae, Family Compositae) is a genus of about 50 species of conspicuous, attractive and widespread plants native to North America. It has a long history of association with human civilization, having been used by North American aboriginals for food and medicine thousands of years ago (1). About 60 years ago, Russian plant breeders began to select varieties of *H. annuus* for high seed oil content, and a new oil crop was developed. Sunflower has become more and more important as an oilseed crop in recent years and now ranks as the second most important source of vegetable oil in the world (2).

Compared to other groups of plants with agricultural significance, little chemical work has been done with sunflowers. In cooperation with a number of other workers, our group at the University of Texas at Austin has initiated a broad investigation of the natural products chemistry of sunflowers. A number of factors have prompted this study. The genus *Helianthus* is still not fully understood systematically (3), and the addition of chemical characters is expected to lead to a better understanding of the interspecific boundaries and evolutionary interrelationships in the genus. Although sunflowers are rich sources of several classes of natural products, little is known about the ecological role of these substances in plants. Hopefully, our work will add to knowledge in this

new and exciting field. Finally, there are important agricultural reasons for studying sunflower chemistry. A thorough understanding of the systematics of *Helianthus* would be an invaluable aid to plant breeders working to improve high oil-yielding cultivars of *H. annuus*. One of the factors limiting the success of sunflower cultivation, particularly in the United States, is damage to the crop caused by insects (4). Many wild species of *Helianthus*, however, appear to be resistant to the same insects that infest the cultivated varieties (5, 6). Since there is no obvious morphological feature in these resistant plants, such as pubescence, which might account for their immunity to predation, this resistance appears to have a chemical basis. Therefore, by studying the chemistry of these plants, we may be able to elucidate the nature of their defenses against insects and this knowledge could be applied in breeding more resistant cultivated sunflowers. Terpenoid compounds have been implicated as plant defensive substances in a number of instances (7), so it is prudent to consider them in a search for defensive principles.

#### TERPENOID CONSTITUENTS OF SUNFLOWERS

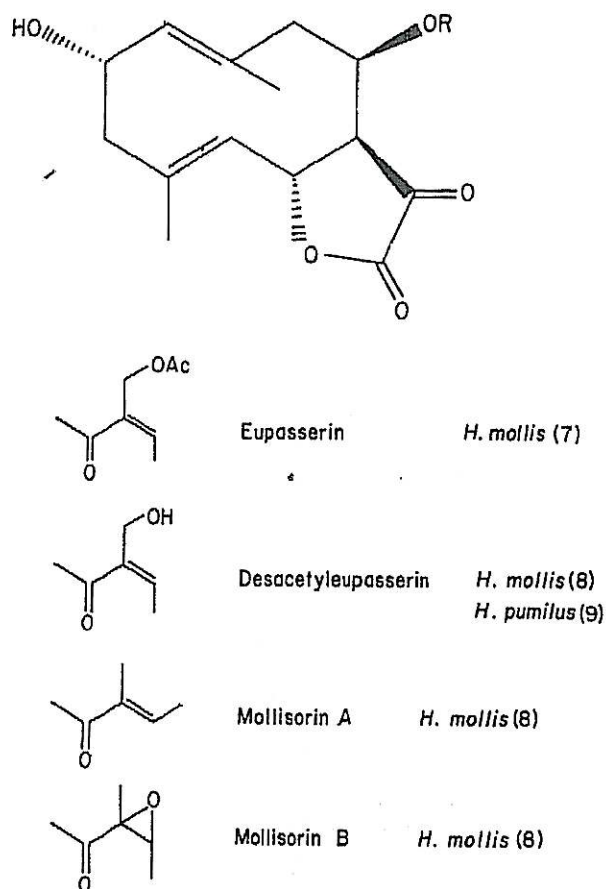
The category "terpenes" embraces a large variety of chemical compounds, all biosynthetically related. The terpenes isolated from sunflowers can be classified into 3 groups: sesquiterpene lactones, diterpenes and triterpenes and steroids.

##### *Sesquiterpene Lactones*

Sesquiterpene lactones are widespread in *Helianthus*; almost all species investigated have proved to contain them. The 18 different compounds isolated to this point belong to 3 basic structural types: germacranolides (12, including 4 germacrolides and 8 heliangolides), eudesmanolides (1) and guaianolides (5). All but one of these show 6, 7 lactonic ring closure and have side chains of 4 or 5 carbons esterified to position 8.

The germacrolides or *trans, trans*  $\Delta^{4,10}$ ,  $\Delta^{4,5}$ -germacranolides are shown in Figure 1. They are very similar, differing only in the nature of their C<sub>8</sub> ester side chains. All were isolated from *H. mollis* (8), and desacetylepasserin was

also found in *H. pumilus* (9).

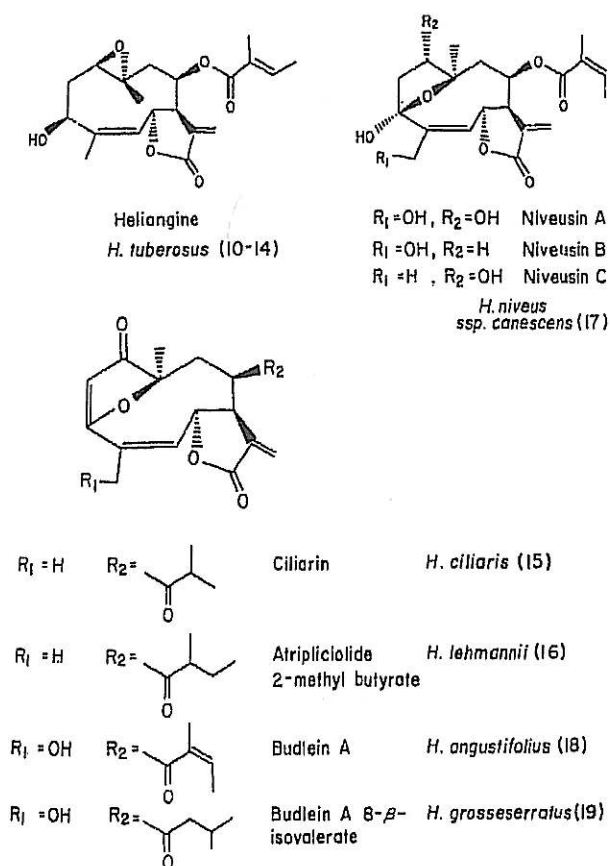


#### GERMACROLIDES FROM HELIANTHUS

Figure 1

Figure 2 depicts the heliangolides extracted from species of *Helianthus*. Heliangine, the first heliangolide known, was isolated in the early 1960's from *H. tuberosus*, the Jerusalem artichoke (10, 11, 12). It is a plant growth regulator with potent anti-auxin activity. It was originally interpreted as a germacrolide ( $\Delta^{4,5}$  *trans*) from X-ray analysis (13), but this was later shown to be incorrect (14).

All the remaining heliangolides (15, 16, 17, 18, 19) have 3,10 cyclic ether bridges, some with 3(2H) furanone moieties and others with 2-OH tetrahydrofuran groups. The structure of ciliarin was also first described incorrectly as a germacrolide (15). Subsequent correlation of the magnitude of the PMR H<sub>6</sub>-H<sub>7</sub> coupling constant with that of woodhousin, a heliangolide (J<sub>6,7</sub> > 3 Hz for heliangolides, J<sub>6,7</sub> = ~ 10 Hz for germacrolides), showed that ciliarin also had to be a member of the heliangolide series (20).

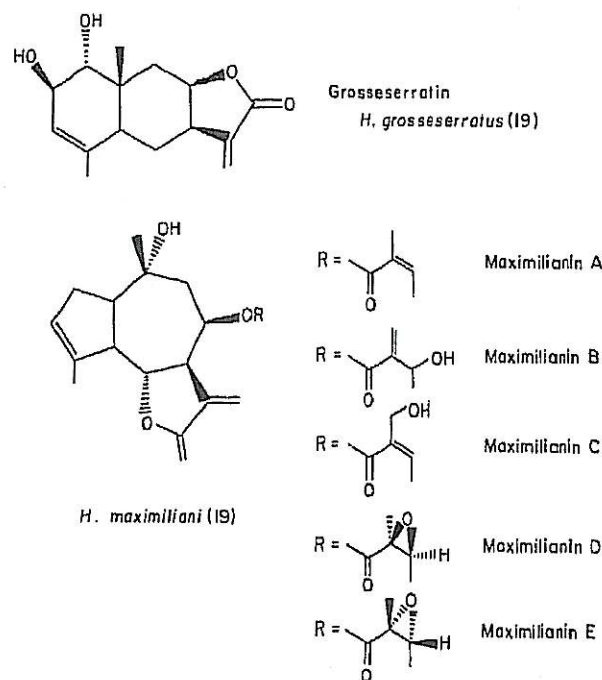


### HELIANGOLIDES FROM *HELIANTHUS*

Figure 2

Representatives of two other classes of sesquiterpene lactones have been found in *Helianthus*, eudesmanolides and guaianolides (Figure 3) (19). The five guaianolides were all isolated from *H. maximiliani* and are very similar, differing from each other only in their five carbon side chains. The single eudesmanolide is very different from other sunflower sesquiterpene lactones. It is the only one that is 7, 8 lactonized and the only one lacking an ester side chain.

The presence of three distinct structural types of sesquiterpene lactones in *Helianthus* puts this genus in the same category as a few other large, well-investigated genera of the Compositae, including *Ambrosia*, *Artemisia*, *Centaurea*, *Chrysanthemum*, *Iva* and *Vernonia*, all of which also show such synthetic versatility (20). The ease with which congeneric species produce different classes of sesquiterpene lactones shows not only the evolutionary flexibility of biosynthetic routes to sesquiterpene lactones, but also the close biosynthetic relationship among the different structural types themselves.



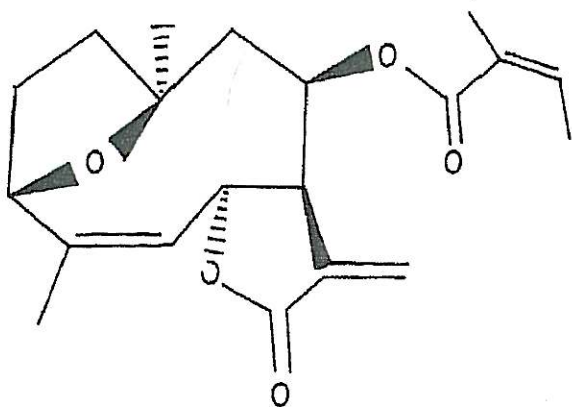
### EUDESMANOLIDES AND GUAIANOLIDES FROM *HELIANTHUS*

Figure 3

#### The Structural Determination of Niveusin A

As an example of the techniques used in determining the structures of sesquiterpene lactones from *Helianthus*, the elucidation of niveusin A (17) will be discussed in detail. Niveusin A was shown to be a typical  $\alpha$ -methylene- $\gamma$ -lactone by the usual spectral evidence: IR (1760, 1650  $\text{cm}^{-1}$ ) and PMR narrowly split doublets,  $J=3$  Hz, at  $\delta$  6.20 and  $\delta$  5.37). The presence of an angelic acid ester was evident from characteristic IR, (1720  $\text{cm}^{-1}$ ), MS ( $m/e$  83, base peak) and PMR data ( $\delta$  5.28,  $qq$ , 1H,  $J=2, 7.5$  Hz;  $\delta$  1.91,  $dq$ , 3H,  $J=1, 7.5$ ;  $\delta$  1.75,  $dq$ , 3H,  $J=1, 2$  Hz). Extensive PMR decoupling experiments at 200 MHz allowed the assignment of signals for protons at positions 5, 6, 7, 8, 9 and 13. The signal for  $H_6$  ( $\delta$  5.14,  $br t$ ,  $J_{5,6} = J_{6,7} = 4$  Hz) showed that niveusin A possessed a heliangolide-type skeleton ( $\Delta^{4,5}$  *cis*) (21), while the abnormally low shift of  $H_7$  ( $\delta$  4.06) along with a calculation from the molecular formula (confirmed by elemental analysis and high resolution MS) of the number of degrees of unsaturation indicated a tetrahydrofuran system with the oxygen bridge oriented in the usual fashion between the 3 and 10 positions (22). These structural features are

summarized in Figure 4. The configurations at  $C_6$ ,  $C_7$ , and  $C_8$  were clear from the PMR coupling constants.



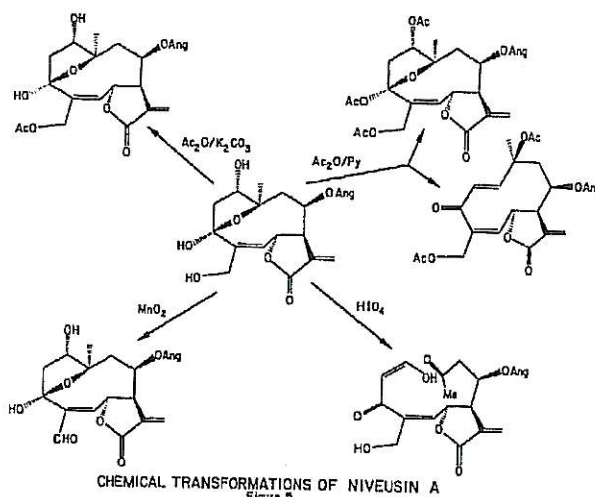
PARTIAL STRUCTURE OF NIVEUSIN A

Figure 4

The molecular formula of niveusin A and its IR and  $^{13}\text{C}$ -NMR spectra suggested the presence of three hydroxyl groups in the molecule. Their placement was the main challenge in the elucidation of its structure. Irradiation of both parts of an AB doublet centered at  $\delta$  3.8 sharpened the signals for protons 5 and 6, indicating the existence of a  $1^\circ$  alcohol function at carbon 15. Acetylation with acetic anhydride and  $\text{K}_2\text{CO}_3$  gave reaction only at this position. A monoacetate was produced with the AB doublet at  $C_{15}$ , shifting downfield (Figure 5). Under more stringent acetylating conditions ( $\text{Ac}_2\text{O}$ -pyridine), a diacetate and a triacetate were formed (Figure 5). In the triacetate only one additional signal underwent a downfield shift, suggesting the existence of a tertiary alcohol which was provisionally assigned to  $C_3$ . The presence of a hemi-ketal function in the molecule was confirmed by a typical low field  $^{13}\text{C}$ -NMR signal at 107 ppm. The diacetate underwent a major skeletal change analogous to that previously observed for tagitinin B (23).

The assignment of the final hydroxyl group to position 1 was made possible by the results of a periodate oxidation (Figure 5). The stereochemistry at  $C_1$  was deduced from the magnitudes of the coupling constants. The *cis* geometry of the  $C_{4,5}$  double bond was confirmed by manganese dioxide oxidation which yielded a product with a  $C_{15}$  aldehyde function. The PMR shift of the

aldehyde proton in this type of molecule varies with the geometry of the bond (24). The structure of niveusin A was confirmed by X-ray crystallography in the laboratory of Dr. William H. Watson at Texas Christian University.



#### Preparing Two-Dimensional Representations of Sesquiterpene Lactones from X-ray Drawings.

In the course of preparing a two-dimensional representation from the X-ray drawing of niveusin A, it became clear that there is some confusion about the proper way to do this. Rogers, Moss and Neidle proposed conventions for drawing germacranolides several years ago, but these have not been universally accepted (25).

Fischer *et al.* discuss this problem in their recent monograph (20, pp. 59-61). Since uninitiated readers might not be able to derive the correct structure from the standard two-dimensional formula without knowing the conventions used in drawing it, we now discuss these conventions. The X-ray drawing and two different two dimensional representations of niveusin A are shown in Figure 6.

The confusion centers on the way to depict configuration when chiral carbon atoms of the ring appear or are drawn with re-entrant angles, that is when they are directed to the inside of the ring, as for position 10 in Figure 6B. Traditionally, carbon atoms 5 and 10 are drawn with re-entrant angles in two-dimensional representations of germacranolides. According to the X-ray drawing (Figure 6A), carbon 10 in niveusin A is not re-entrant, but rather apical. However, since con-

vention dictates that this position be drawn in re-entrant fashion in a two-dimensional representation, as in Figure 6B, it is necessary to twist carbon 10 in towards the interior of the ring to achieve the desired configuration. When this is done, the stereochemistry at this position is reversed (compare Figure 6A with 6B).

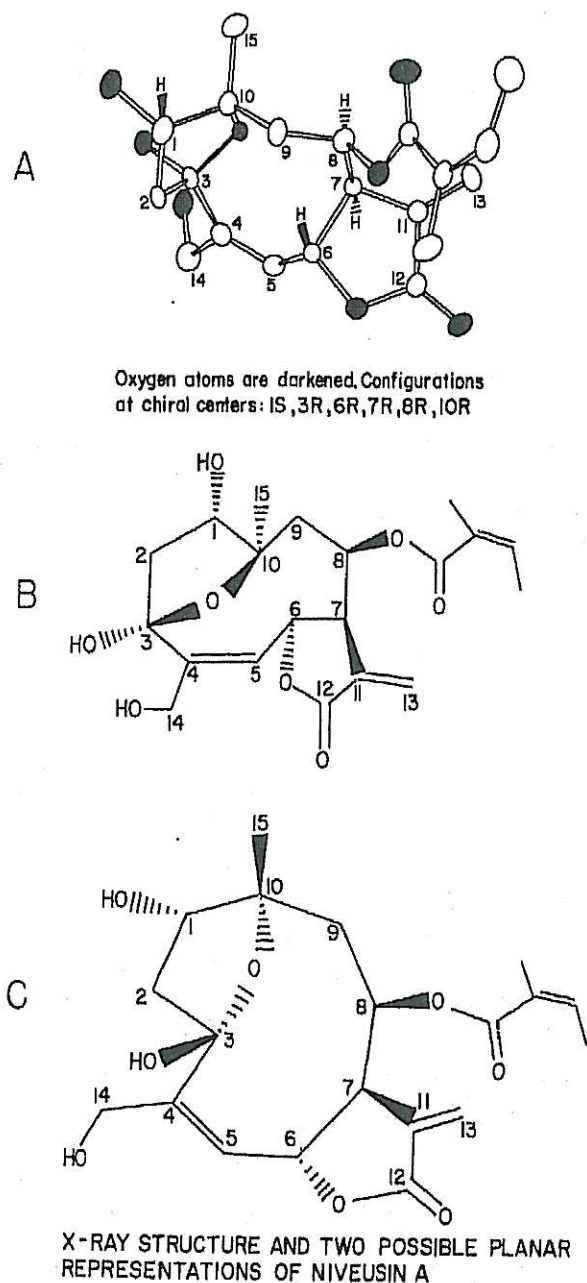


Figure 6

By contrast, carbon 3 is genuinely a re-entrant carbon in the X-ray drawing, but is usually drawn apically in standard formulae. Position 3 must therefore be twisted away from the center of the ring to achieve conventional representation and this also reverses the stereochemistry.

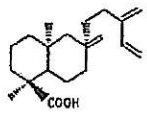
The other re-entrant angle in the normal depiction of heliangolides occurs at position 6. Since this carbon is not re-entrant in the X-ray drawing, logic would suggest that the chirality at this position be inverted in preparing a two-dimensional representation. However, this is not the case. The stereochemistry at position 6 is drawn as if it were an apical carbon, a legacy of the way germacranolides are usually depicted. Clearly, in all future work, the relative configurations (or absolute configurations, when known) at positions like 3, 6, and 10 should be specified to avoid any possibility of misunderstanding. We suggest that in the future structures like niveusin A be presented in a fashion much closer to the actual X-ray drawing, as in Figure 6C. In this approach, which follows closely the proposals of Rogers *et al.* (25), re-entrant angles that do not "correspond to reality", such as those traditionally used at positions 5 and 10, are avoided.

### Diterpenes

Diterpenes are another class of natural products that are wide-spread in sunflowers, having been found in the extracts of nearly every species examined so far (Figure 7) (17-19, 26-34). Three distinct skeletal types are common the bicyclic labdane, the tetracyclic kaurane and the pentacyclic trachylobane. Phyllocladine and hibaene type diterpenes have also been reported though structures with these skeletons have not been fully characterized (32). The kaurane type is the most important both in the number of structures known and the number of species in which they have been found.

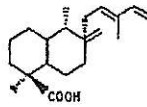
Most of the 13 different diterpenes known from *Helianthus* are carboxylic acids; of the remaining ones, two are alcohols and one is a lactone. Unlike the sunflower sesquiterpene lactones, which as a group are found almost exclusively in species of *Helianthus*, most of the diterpenes are also known from other groups of plants. For example 15- $\alpha$ -hydroxy-(-)-kaur-16-en-19-oic acid (grandifloric acid) has been isolated from *Espeletia* (35) and *Enhydra* (36), both in the Compositae, while kaur-16-en-19-oic acid itself is known from over 10 different genera besides *Helianthus*, including several outside the Compositae, such as *Aralia* (Araliaceae) (37) and *Annona* (Annonaceae) (38).

## LABDANE TYPE



Cis-ozic acid

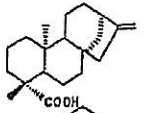
*H. angustifolius* (18)  
*H. maximiliani* (19)  
*H. occidentalis* (33)



Trans-ozic acid

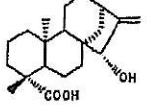
*H. occidentalis* (33)

## KAURANE TYPE

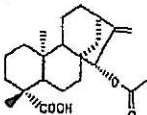


Kaur-16-en-19-oic acid

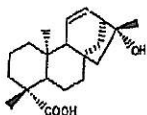
*H. annuus* (26,27)  
*H. debilis* ssp. *debilis* (31)  
*H. niveus* ssp. *canescens*  
*H. occidentalis* (34) (17)

15- $\alpha$ -Hydroxy-kaur-16-en-19-oic acid (Grandifloric acid)

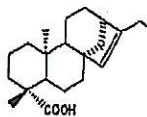
*H. annuus* (28,29)  
*H. grosseserratus* (19)  
*H. niveus* ssp. *canescens* (17)

15- $\alpha$ -Angeloyloxy-kaur-16-en-19-oic acid (Angeloylgrandifloric acid)

*H. annuus* (28)  
*H. debilis* ssp. *debilis* (31)

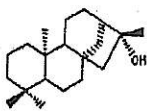
DITERPENES FROM HELIANTHUS16- $\alpha$ -Hydroxy-kaur-11-en-19-oic acid

*H. angustifolius* (18)  
*H. argophyllus* (19)  
*H. ciliaris* (18)  
*H. salicifolius* (18)

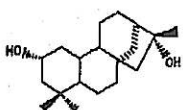


17-Hydroxy-kaur-15(16)-en-19-oic acid

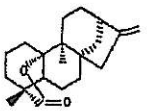
*H. grosseserratus* (19)

16- $\alpha$ -Hydroxy-kaurane

*H. argophyllus* (19)

2- $\alpha$ ,15- $\alpha$ -Dihydroxy-kaurane

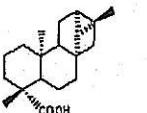
*H. argophyllus* (19)  
*H. niveus* ssp. *canescens*  
*H. salicifolius* (19) (19)



Tetrachyrin

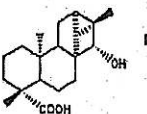
*H. debilis* ssp. *debilis* (31)

## TRACHYLOBANE TYPE

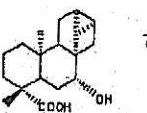


Trachyloban-19-oic acid

*H. annuus* (26, 27)

15- $\alpha$ -Hydroxytrachyloban-19-oic acid

*H. annuus* (29)

7- $\alpha$ -Hydroxytrachyloban-19-oic acid

*H. argophyllus* (19)  
*H. ciliaris* (30)  
*H. grosseserratus* (19)  
*H. laciniatus* (32)  
*H. niveus* ssp. *canescens*  
*H. salicifolius* (19) (17)

Figure 7

## Triterpenes

The third class of terpenoids extracted from sunflowers includes triterpenes and steroids (Figure 8). All of the work in this category has focused on *H. annuus*, the widespread, weedy species which has served as the principal source of germplasm in the development of cultivated sunflowers. A number of triterpene alcohols, diols and triols have been isolated from many organs of this plant, particularly the flowers (Figure 8) (39-41). Triterpene alcohols are characteristically found in yellow flowers of the Compositae (39, 42). Several saponins have also been extracted from the flowers (43-47), although only the two shown in Figure 8 have been fully characterized. Both of these are glycosides of echinocystic acid (45, 46). The uncharacterized saponins also have echinocystic acid sapogenins or the similar  $\beta$ -amyrin-type moieties oleanolic and albigenic acid (43, 47). Finally, many sterols have been reported in the seed oil of *H. annuus* (34, 48, 52). These are mostly widespread, nearly ubiquitous compounds such as cholesterol and  $\beta$ -sitosterol, although a few of the  $\Delta^{7,24}$  stigmasterol derivatives are unusual.

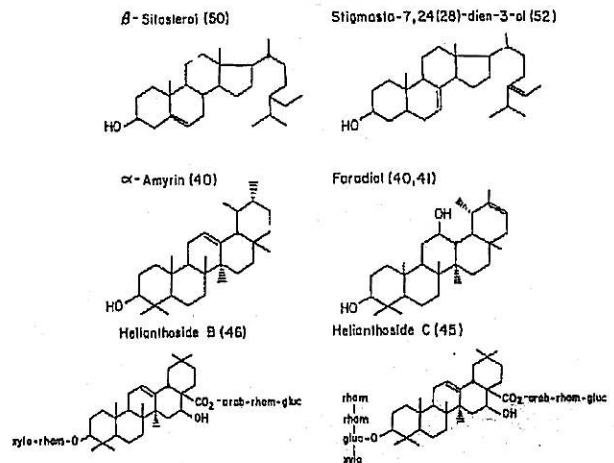
SOME STEROLS, TRITERPENOLS AND SAPONINS FROM HELIANTHUS ANNUUS

Figure 8

## DISCUSSION

Having reviewed the major classes of terpene compounds in *Helianthus*, it is interesting to examine the terpenoid chemistry of the genus in a wider context. *Helianthus* is a member of the Compositae, a family that produces a very large variety of secondary plant products, many of

which are quite distinctive. Included among these are four major types of terpenes- essential oils containing volatile monoterpenes and sesquiterpenes. Sesquiterpene lactones and triterpene alcohols are both very characteristic metabolites of the family, found in very few other parts of the plant kingdom. *Helianthus* has so far been shown to contain representatives of 3 of these 4 major types of terpenoids and so fits in well with what one might have predicted given a knowledge of the chemistry of the family.

Within the Compositae, sesquiterpene lactones are not uniformly distributed. In some of the 13 classical tribes, such as the Astereae and the Mutisieae, they are of sparse occurrence and the compounds themselves belong to a few simple structural types. In other tribes, however, including the Heliantheae and the Anthemideae, sesquiterpene lactones are widely distributed and a large degree of structural complexity is evident (53). The tribe Heliantheae contains most of the different skeletal types found in the rest of the family (54), so it is not surprising that its nominative genus, *Helianthus*, contains a fair assortment of these.

Another family-wide trait is the presence of oleanolic acid and its derivatives as the principal saponogens in saponin-accumulating taxa (42). These are also found in *Helianthus*.

At the beginning of this paper, we mentioned that the systematics of *Helianthus* are still not fully understood and held out the hope that chemical investigation would lead to a better understanding of relationships within the genus. Unfortunately, one cannot observe any systematic trends in the chemical data at this stage. However, since collections of only a small percentage of the species have been examined and the terpenoid patterns of each species are very distinct, we are hopeful that chemical characters will prove taxonomically useful in the future. The diterpenes may prove to be more valuable systematically than the sesquiterpene lactones because the same diterpenoids often occur in several species, whereas almost all of the sesquiterpene lactones are unique to just a single species.

In conclusion, we would like to discuss the possible implications that a knowledge of *Helian-*

*thus* terpenoid chemistry could have for sunflower cultivation. The importance of sunflower as an oilseed crop has increased dramatically in recent years, and it now ranks as the second most important oil crop in the world behind soybean (2). In the United States, cultivation has increased fifty-fold in the last 10 years. Insect problems, though, significantly limit the yield and range of cultivation. However, as mentioned previously, many wild *Helianthus* species are resistant to the serious pests of the cultivated forms and this phenomenon is believed to have a chemical basis. Of the compounds discussed, sesquiterpene lactones and diterpenes are known to serve as insect feeding deterrents in other plants (55, 56), and sesquiterpene lactones and diterpenes are found in all wild, resistant species investigated so far, while no sesquiterpene lactone has ever been isolated from one of the cultivars. Therefore, terpenoids may be important in the resistance of sunflowers to insect pests.

We are now sending purified *Helianthus* terpenes to collaborating scientists at the U.S. Department of Agriculture who are testing their effects on sunflower pests. If these compounds prove to be effective inhibitors of insect feeding or growth and development, they could be used as insecticides directly (if they can be economically produced) or increased concentrations could be bred into cultivated strains to reduce insect predation.

Increased insect resistance would boost world sunflower production and could also be of great benefit to world health since sunflower oil is lower in saturated fatty acids and higher in unsaturated fatty acids than most other vegetable oils in common use, including corn, cottonseed, soybean and coconut oils (57, 58). Recent studies have shown that substitution of unsaturated fatty acids for saturated ones in the diet lowers blood cholesterol levels. Since high blood cholesterol levels have been tentatively linked with increased incidence of heart attacks (58), a relative increase in the consumption of sunflower oil might help in reducing one of our most serious health problems.

NOTE: Since the preparation of this manuscript, several additional papers on the terpenoid constituents of *Helianthus* have appeared (59-61).

## ACKNOWLEDGMENTS

This work was supported by the National Science Foundation (DEB 76-09320), the National Institutes of Health (HD-04488), the Robert A. Welch Foundation (Grant F-130) and the Sunflower Association of America. The authors are indebted to Drs. V. Zabel and W.H. Watson for the X-ray analysis of niveusin A, Dr. B. Timmermann for preparing the Spanish translation of the abstract, and Drs. W. Herz and N.H. Fischer for their useful comments on the two-dimensional representation of sesquiterpene lactones.

## REFERENCES

- Heiser, C.B. 1976. *The Sunflower*. University of Oklahoma Press, Norman, Oklahoma. 198 pp.
- Putt, E.D. 1978. History and present world status. In "Sunflower Science and Technology" (J.F. Carter, ed.) American Society of Agronomy, Madison, Wisconsin. pp 1-29.
- Heiser, C.B. 1969. The North American sunflowers (*Helianthus*). *Mem. Torr. Bot. Club* 22: 1-218.
- Schulz, J.T. 1978. Insect pests. In "Sunflower Science and Technology" (J.F. Carter, ed.) American Society of Agronomy, Madison, Wisconsin. pp 169-223.
- Rogers, C.E. and T.E. Thompson. 1978. Resistance of wild *Helianthus* species to an aphid, *Masonaphis masoni*. *J. Econ. Entomol.* 71: 221-222.
- Rogers, C.E. and T.E. Thompson. 1978. Resistance in wild *Helianthus* to the sunflower beetle. *J. Econ. Entomol.* 71: 622-623.
- Mabry, T.J. and J.E. Gill. 1979. Sesquiterpene lactones and other toxic terpenoids. In "Herbivores: Their Interaction with Secondary Plant Metabolites" (G.A. Rosenthal and D.H. Janzen, eds.) Academic Press, New York, pp. 501-537.
- Ohno, N. and T.J. Mabry. 1979. Germacranolides in *Helianthus mollis*. *Phytochem.* 18: 1003-1006.
- Herz, W. and R. DeGroot. 1977. Desacetylepuserin and nevadensin from *Helianthus pumilus*. *Phytochem.* 16: 1307-1308.
- Morimoto, H., Y. Sanno and H. Oshio. 1966. Chemical studies on heliangine, a new sesquiterpene lactone isolated from the leaves of *Helianthus tuberosus*. *Tetrahedron* 22: 3173-3179.
- Iriuchijima, S., S. Kuyama, N. Takahashi and S. Tamura. 1966. Structure of heliangine, a novel ten-membered sesquiterpene lactone. *Agr. Biol. Chem.* 30:511-512.
- Iriuchijima, S., S. Kuyama, N. Takahashi and S. Tamura. 1966. Chemistry of heliangine. Part 1. Structure of heliangine. *Agr. Biol. Chem.* 30: 1152-1163.
- Nishikawa, M., K. Kamiya, A. Takabatake, H. Oshio, Y. Tomiie and I. Nitta. 1966. The X-ray analysis of dihydroheliangine monochloroacetate. *Tetrahedron* 22: 3601-3606.
- Neidle, S. and D. Rogers. 1972. X-ray determination of the structure and absolute configuration of a novel sesquiterpenoid, melampodin. *JCS Chem. Comm.* 140-141.
- Ortega, A., A. Romo de Vivar, E. Diaz and J. Romo. 1970. Determinación de las estructuras de la calaxina y de la ciliarina, nuevos germacranolidos furanonicos. *Rev. Latinoamer. Quím.* 1: 81-85.
- Bohlmann, F. and L.N. Dutta. 1979. Ein Neues Heliangolid aus *Helianthus lehmannii*. *Phytochem.* 18: 676.
- Ohno, N. and T.J. Mabry. 1980. Sesquiterpene lactones and diterpene carboxylic acids in *Helianthus niveus* ssp. *canescens*. *Phytochem.* 19: 609-614.
- Ohno, N., J. Gershenzon, P. Neuman and T.J. Mabry. 1980. Diterpene carboxylic acids and a heliangolide from *Helianthus angustifolius*. *Phytochem.* submitted.
- Gershenzon, J., N. Ohno, P. Neuman and T.J. Mabry. Unpublished results.
- Fischer, N.H., E.J. Olivier and H.D. Fischer. 1979. The biogenesis and chemistry of sesquiterpene lactones. *Prog. Chem. Org. Nat. Prod.* 38: 47-390.
- Herz, W. and S.V. Bhat. 1972. Woodhousin, a new germacranolide from *Bahia woodhousei*. *J. Org. Chem.* 37: 906-912.
- Romo de Vivar, A., C. Guerrero, E. Diaz and A. Ortega. 1970. Structure and stereochemistry of zexbrevin, a 3(2H) furanone germacranolide. *Phytochem.* 26: 1657-1664.
- Pal, R., D.K. Kulshreshtha and R.P. Rastogi. 1976. Chemical constituents of *Tithonia tagitiflora*. II. Structure of tagitinin B by application of homonuclear INDOR spectroscopy. *Indian J. Chem.* 14B: 77-80.
- Herz, W. and P.S. Kalyanaraman. 1975. Acanthospermal A and acanthospermal B, two new melampolides from *Acanthospermum* species. *J. Org. Chem.* 40: 3486-3491.
- Rogers, D., G.P. Moss and S. Neidle. 1972. Proposed conventions for describing germacranolide sesquiterpenes. *JCS Chem. Commun.*, 142.
- Pyrek, J.S. 1970. New pentacyclic diterpene acid, trychloban-19-dioic acid from sunflower. *Tetrahedron* 26: 5029-5032.
- Kasprzyk, Z., W. Janiszewska and M. Papaj. 1974. Diterpenic acids of *Helianthus annuus*. *Bull. Acad. Pol. Sci., Ser. Sci. Biol.* 22: 1-4.
- Martin Panizo, F. and B. Rodriguez. 1979. Algunos componentes diterpenicos del girasol (*Helianthus annuus*). *An. Quím.* 75: 428-430.
- McCrindle, R. Unpublished results.
- Bjeldanes, L.F. and T.A. Geissman. 1972. Constituents of *Helianthus ciliaris*. *Phytochem.* 11: 327-332.
- Ohno, N., T.J. Mabry, V. Zabel and W.H. Watson. 1979. Tetrachyrin, a new rearranged kaurenoid lactone, and diterpene acids from *Tetrachyron orizabaensis* and *Helianthus debilis*. *Phytochem.* 18: 1687-1689.
- Ortega, A., A. Ayala, C. Guerrero and A. Romo de Vivar. 1972. Aislamiento y caracterización de algunos componentes terpenoides del *Helianthus laciniatus*. *Rev. Soc. Quím. Mex.* 16: 191.
- Stipanovic, R.D., D.H. O'Brien, C.E. Rogers and T.E. Thompson. 1979. Diterpenoid acids, (-)-cis- and (-)-trans ozic acid, in wild sunflower, *Helianthus occidentalis*. *J. Agric. Food Chem.* 27: 458-459.
- Stipanovic, R.D. and D.H. O'Brien. Unpublished results.
- Usbillaga, A., J. de Hernández, N. Perez and M. Kiriakidis. 1973. Kauranoid diterpenes in *Espeletia* species. *Phytochem.* 12: 2999.
- Ali, E., P.P. Ghosh Dastidar and S.C. Pakrashi. 1974. Studies on Indian medicinal plants. Part XXIX. Diterpenoid and other constituents of *Enhydra fluctuans*. *J. Indian Chem. Soc.* 51: 409-418.
- Shibata, S., S. Mihashi and O. Tanaka. 1967. The occurrence of a (-) pimarane-type diterpene in *Aralla cordata*. *Tetr. Lett.* 4241-5243.
- Eshiet, I.T.U., A. Akisanya and D.A.H. Taylor. 1971. Diterpenes from *Annona senegalensis*. *Phytochem.* 10: 3294-3295.
- Kasprzyk, Z. and T. Kozłowska. 1966. Distribution of sterols and triterpenic alcohols in plants of the Compositae family. *Bull. Acad. Pol. Sci., Ser. Sci. Biol.* 14: 645-649.
- Kasprzyk, Z. and W. Janiszewska. 1971. Triterpenic alcohols from the shoots of *Helianthus annuus*. *Phytochem.* 10: 1946-1947.
- Pyrek, J.S. and E. Baranowska. 1973. Faradiol and arnidiol-revision of the structure. *Tetr. Lett.* 809-810.
- Hegnauer, R. 1977. The chemistry of the Compositae. In "The Biology and chemistry of the Compositae, Vol. 1" (V.H. Heywood, J.B. Harborne and B.L. Turner, eds.) Academic Press, London. pp 283-335.
- Kasprzyk, Z., Z. Wojciechowski and I. Kuczevska-Jankowska. 1966. The glucosides of triterpenic acids from *Helianthus annuus* flowers. *Bull. Acad. Pol. Sci., Ser. Sci. Biol.* 14: 747-749.
- Chirva, V. Ya., P.L. Cheban and G.V. Lazur'evskii, 1968. Sunflower saponins. *Khim. Prir. Soedin.* 4, 140. (cited in Chemical Abstracts).
- Cheban, P.L., V. Ya Chirva and G.V. Lazur'evskii, 1969. Structure of helianthoside C, a sunflower saponin. *Khim. Prir. Soedin.* 5: 129-130. (cited in Chemical Abstracts).
- Cheban, P.L. and V. Ya. Chirva. 1969. Structure of helianthoside



- B, *Khim. Prir. Soedin.*, 5: 327. (cited in Chemical Abstracts).
47. Wojciechowski, Z., L. Anysz-Loos, P. Szybek, H. Ukrainka and Z. Kasprzyk. 1971. Structure of glycosides of triterpenic acids from the flowers of *Helianthus annuus* (sunflower). *Bull. Acad. Pol. Sci., Ser. Sci. Biol.* 19: 179-182.
48. Kasprzyk, Z. and J.S. Pyrek. 1967. Sterols of five plants of the Compositae family. *Rocz. Chem.* 41: 201-208. (cited in Chemical Abstracts).
49. Wurziger, J. and L. Schumann. 1968. Investigation and adjudgement of sunflower oils of natural purity. *Fette, Seifen, Anstrichm.* 70:729-733. (Cited in Chemical Abstracts).
50. Gracian-Tous, J. and J. Martel. 1969. Composition of the sterol fraction of vegetable fats as determined by gas chromatography. *Grasas Aceites* 20: 231-234. (cited in Chemical Abstracts).
51. Sawicki, J. and F. Mordret. 1970. 4-Methyl sterols: constituents of the unsaponifiable fraction of vegetable oils. *Rev. Fr. Corps Gras.* 17: 685-688. (cited in Chemical Abstracts).
52. Homberg, E.E. and H.P.K. Schiller. 1973. Neue Sterine in *Helianthus annuus*. *Phytochem.* 12: 1767-1773.
53. Herz, W. 1977. Sesquiterpene lactones in the Compositae. In "Biology and Chemistry of the Compositae, Vol. 1" (V.H. Heywood, J.B. Harborne and B.L. Turner, eds.) Academic Press, London, pp. 337-357.
54. Swain, T. and C.A. Williams. 1977. Heliantheae- chemical review. In "Biology and Chemistry of the Compositae, Vol. II" (V.H. Heywood, J.B. Harborne and B.L. Turner, eds.) Academic Press, London, pp. 673-697.
55. Elliger, C.A., D.F. Zinkel, B.G. Chan and A.C. Waiss, Jr. 1976. Diterpene acids as larval growth inhibitors. *Experientia* 32: 1364-1366.
56. Burnett, W.C., S.B. Jones, Jr., T.J. Mabry and W.G. Padolina. 1974. Sesquiterpene lactones: insect feeding deterrents in *Vernonia*. *Biochem. Syst. & Ecol.* 2: 25-29.
57. Dorrell, D.G. 1978. Processing and utilization of oilseed sunflower. In "Sunflower Science and Technology" (J. F. Carter, ed.) American Society of Agronomy, Madison, Wisconsin, pp. 407-440.
58. Doty, Harry O., Jr. 1978. Future of sunflower as an economic crop in North America and the world. In "Sunflower Science and Technology" (J.F. Carter, ed.) American Society of Agronomy, Madison, Wisconsin, pp. 457-488.
59. Bohlmann, F., J. Jakupovic, R.M. King and H. Robinson. 1980. Neue ent-Atisiren- und ent-Kaurensäure-derivate aus *Helianthus* arten. *Phytochem.* 19: 863-868.
60. Herz, W. and N. Kumar. 1981. Heliangolides from *Helianthus maximiliani*. *Phytochem.* 20: 93-98.
61. Herz, W. and N. Kumar. 1981. Sesquiterpene lactones from *Helianthus grosseserratus*. *Phytochem.* 20: 99-104.

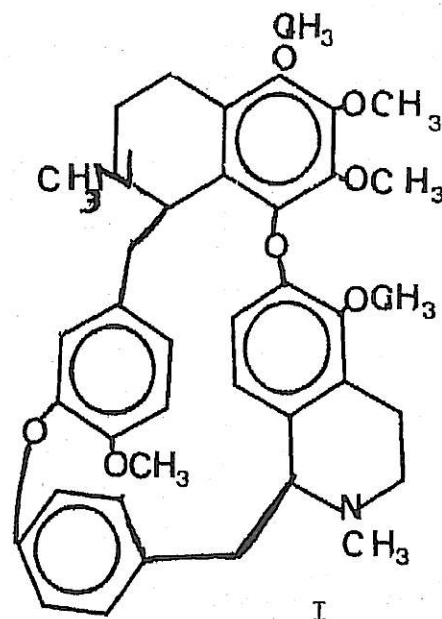
## PLANTAS MEDICINALES DE MEXICO XLVI COMPUESTOS AISLADOS DE LA RAIZ DEL *THALICTRUM DIOICUM*. L.

X.A. Domínguez, R. Franco O., G. Cano C., S. García y Socorro Tamez R.

Depto. de Química  
I.T.E.S.M.  
Monterrey, N.L., México

**ABSTRACTS:** From the methanolic extracts of the roots of *Thalictrum dioicum* L.  $\beta$ -Sitosterol; *m*-meconine and the alkaloids, thallicminine and berberine were isolated.

El cocimiento de la raíz del costipatli (medicina amarilla) (*Thalictrum Hernandezzi*), Ranunculaceae se ha usado para aliviar dolores de los riñones y como diurético<sup>1</sup>. Velázquez<sup>2</sup> aisló un nuevo alcaloide de la bis-bencilisoquinolina, al cual Padilla y Herran llamaron hernandezina<sup>3</sup> y le asignaron una estructura que Shamma *et al*<sup>4</sup> corrigieron a I.



I  
Hernandezina