

# Bibliometric analysis of publications by South African viticulture and oenology research centres

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We analysed the production, impact factor of, and scientific collaboration involved in viticulture and oenology articles associated with South African research centres published in international journals during the period 1990–2009. The articles under scrutiny were obtained from the Science Citation Index database, accessed via the Web of Knowledge platform. The search strategy employed specific viticulture and oenology terms and was restricted to the field ‘topic’. The results showed that 406 articles were published during the review period, with the most number of publications being in the *South African Journal of Enology and Viticulture* ( $n = 34$ ), *American Journal of Enology and Viticulture* ( $n = 16$ ) and *Journal of Agricultural and Food Chemistry* ( $n = 16$ ). The articles were published by 851 authors from 236 institutions. The collaboration rate was 3.7 authors per article, having grown over the two decades examined. The most productive institutions (i.e. those receiving a greater number of citations) were Stellenbosch University (219 published articles and 2592 citations) and the Agricultural Research Council (49 published articles and 454 citations), both from South Africa. Graphical representation of co-authorship networks identified 18 groups of authors and a single network of institutions whose core is Stellenbosch University. In conclusion, we have identified a significant growth in South African viticulture and oenology research in recent years, with a high degree of internationalisation and a constant level of domestic collaboration.

## Introduction

The cultivation area of vineyards in South Africa is located in a narrow belt of Mediterranean climate on the slopes of mountains and valleys in the Western Cape Province. Good soil and climatic conditions have made it possible for nearly 4500 grape growers to cultivate 106 000 hectares of vineyards in this region. There were 493 private wineries and a total of 573 cellars in 2011. Although production was previously dominated by white wines, there is now a tendency towards a greater balance between the production of white and red wines, as well as distillates. These tendencies have also led to an increased interest in the treatment of wastewater from this growing wine industry.<sup>1,2,3,4,5</sup>

South Africa is one of the most prolific New World wine producing countries. With an annual output of 600 million litres, it is the ninth largest producer of wine in the world. Exports constitute about one quarter of this production, but an increase in international sales has been observed over the last decade.<sup>6</sup> The increasing importance of the South African wine industry in both the domestic and international markets has been accompanied by an increase in research activities in wine-related subject areas. In addition to studies carried out on different grapevine diseases,<sup>7,8,9,10</sup> efforts to geographically characterise wine and spirits regions, as well as the development of indigenous varieties and alcoholic beverages are increasing.<sup>11,12,13,14</sup> Thus far, there has been no comprehensive analysis of wine-related research such as has been carried out in other areas of scientific activity in South Africa, for example, Medicine,<sup>15</sup> Bioinformatics,<sup>16</sup> Engineering<sup>17</sup>, and HIV and AIDS.<sup>18</sup> Trends and implications of South Africa’s scientific outputs have also recently been studied.<sup>19</sup>

Articles published in scientific journals are one of the measurable outcomes of research activity, and may be analysed by qualitative and quantitative methods. The qualitative ‘peer review’, based on expert opinion is an indispensable basic condition imposed by editors before research will be published in prestigious journals. The quantitative determination is based on a series of measures or indicators that are derived from statistical analysis of published scientific literature and included in bibliographic databases.<sup>20,21,22</sup> These indicators measure the scientific activity of researchers and their institutions, given that they determine the articles that have been published, their literature characteristics as well as establishing collaborative relationships with each other. Authors can extend credit to colleagues’ publications by quoting them so that the citation counts reflect the impact that published articles have had on previous publications and their authors.<sup>23,24</sup>



Scientific collaboration facilitates the flow of information amongst researchers in order to share costs and improve efficiency in research.<sup>25,26,27,28</sup> One way of determining the level of established cooperation is by counting the number of co-authorships amongst authors involved in an area of scientific research. The co-authorship relationship occurs when two or more authors or institutions simultaneously contribute to the same scientific article.<sup>28,29</sup> These interpersonal and interinstitutional collaborations between researchers can be represented by graphs, using social network analysis, which quantify how many members make up a network, what the intensity of the relationship is between its members and who are the most relevant.<sup>28,30,31</sup> Researchers with the largest number of collaborative publications with other authors are at the 'research front' of that area.<sup>32,33</sup>

The aim of this article was to analyse the scientific activity of researchers in South Africa in viticulture and oenology by using bibliographic analyses of articles in the Science Citation Index (SCI) during the period 1990–2009. The length of the analysed time period allowed us to obtain comprehensive information with which to establish trends of research in the area. Moreover, the joint analyses of productivity, collaboration and scientific impact provides a global and integrated vision of the country's research in this area.

## Methods and data sources

As in other bibliometric studies,<sup>19</sup> the articles under analyses were obtained from the SCI database, accessed via the Web of Knowledge platform from terminals at Stellenbosch University (Western Cape, South Africa). For the definition of the research field 'wine research', we used a strategy similar to that employed by Glanzel and Veugelers<sup>34</sup> in a previous article published in the *American Journal of Enology and Viticulture*. The delineation of the area was based on a search strategy combining two components, (1) specific search strings, and (2) core journals. According to these authors, this set of search terms was the result of a series of previous strategies tested for the data retrieval. The search strategy employed the following terms: barrel fermentation, cava, champagne\*, charmant, enolog\*, grapevine, grapevines, icewine\*, malolactic fermentation, vine\*, vineyard, viticultur\*, vitis vinifera, wine\*, winemaker\*. The search was restricted to the field 'topic', which retrieves matching records if the aforementioned terms are included in the titles, keywords or abstracts of articles. In some terms the root was used (cutting the word with an asterisk) to obtain all the documents associated with the derived words (e.g. by using the truncation enolog\*, the SCI database finds enology, enological, enologist, etc.). As a result of this search, all articles in the following SCI specific viticulture and oenology journals were obtained: *American Journal of Enology and Viticulture*, *Australian Journal of Grape and Wine Research*, *Ciencia e Técnica Vitivinícola*, *Journal International des Sciences de la Vigne et du Vin*, *South African Journal of Enology and Viticulture* and *Vitis*. Finally, we limited the search to articles that were co-authored by at least one author from a South

African institution, by including the word 'South Africa' in the 'address' field of the search options.

The analysis was limited to 20 years (the period from 1990 to 2009) and to research articles, including original articles, reviews, letters and editorials, but excluding book reviews, summaries of communications at conferences, reprints, news and bibliographic articles. All records obtained were manually reviewed to ensure their relevance.

The final records were exported to a relational database using the proprietary software Bibliometric.<sup>35</sup> The different variants of the names of the same author or institution were unified because this information was not always standardised in SCI. The information was then analysed to obtain bibliometric indicators and to identify all combinations of pairs of authors and institutions in each article, quantifying the number of co-authorships, that is, the presence of joint signatures of authors or institutions in different articles. This information formed the basis for identifying research groups. The software Pajek, designed for the analysis and visualisation of networks<sup>36</sup> was used for the construction and graphic representation of the research groups.

## Results

### General data: Annual productivity and journals

During the 1990–2009 period 406 articles were published, consisting of 373 original articles (91.9%), 23 reviews (5.7%), 6 letters (1.5%) and 4 editorials (0.9%). The majority of articles (53.2%) were published in the last 5 years (Figure 1), with 2007 being the most productive year ( $n = 52$ ). With the exception of Australia, all countries had a similar productivity pattern of about 200 scientific publications in the last 5 years; South Africa and Chile were particularly similar.

A total of 22 journals had four or more published articles on viticulture and oenology (Table 1). The 406 articles were published in 193 journals; the *South African Journal of Enology*

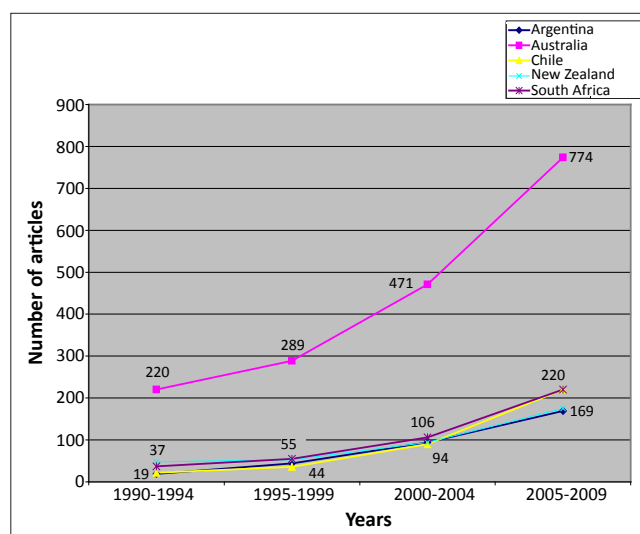


FIGURE 1: The number of articles published between 1990 and 2009 by the most important wine-producing nations in the southern hemisphere.



and *Viticulture* published the most articles (34), followed by the *American Journal of Enology and Viticulture* and the *Journal of Agricultural and Food Chemistry* (both with 16 articles). The journals with the highest impact factors were *Studies in Mycology* (6.349), *Journal of Chromatography* (4.101) and *Applied and Environmental Microbiology* (3.686).

### Author productivity and citations

The 406 articles were published by 851 different authors, of whom 628 (73.8%) appeared only once (Table 2). The most productive author was Isak S. Pretorius with 40 articles, followed by Pieter W. Crous (19 articles) and Pierre van Rensburg and Florian F. Bauer (18 articles each). As far as the citations are concerned, 83.3% of the authors were cited at least once and the remaining 16.7% received no citations. The most cited authors were Isak S. Pretorius (856 citations) and Hennie J.J. van Vuuren (321 citations). Five authors are not included in Table 2 because they published only one article that received 290 citations: M.I. Gil, F.A. Tomas-Barberan, B. Hess-Pierce, D.M. Holcroft and A.A. Kadewr. Following these authors are Florian F. Bauer (282 citations), P.W. Crous (279 citations) and M.G. Lambrechts (273 citations).

### Institutional productivity and citations

A total of 236 institutions were given in the published articles. Stellenbosch University contributed the most publications (219), followed by the Agricultural Research Council (Infruitec-Nietvoorbij, Stellenbosch) with 49 and the Universities of Cape Town and Pretoria with 32 and 31, respectively (Table 3). Because the literature search was limited to articles that were signed by South African institutions, foreign institutions who published an article

in conjunction with them, such as the Australian Wine Research Institute, Centraalbureau voor Schimmelcultures (the Netherlands), University of Guelph (Canada), Ghent University (Belgium), Agricultural Research Service (US Department of Agricultural), University of Castilla-La Mancha (Spain) and Universität Zürich (Switzerland) are also listed in Table 3. The most cited institution was Stellenbosch University ( $n = 2592$ ), followed by the Agricultural Research Council (Infruitec-Nietvoorbij, Stellenbosch) ( $n = 454$ ) and Consejo Superior de Investigaciones Científicas (Spain) ( $n = 342$ ).

### Indicators of collaboration and networks

The collaboration index (the average number of authors per article) was 3.7 for the whole period under investigation, increasing from 2.7 in the first 10 years to 3.9 in the last 10 years (results not shown). Regarding collaboration between institutions, 130 articles (31.1%) were produced with domestic collaboration, 156 (37.3%) with international collaboration and 132 with no collaboration (31.6%). The percentage of articles produced with international collaboration increased over the period analysed, from 16.2% in the 1990–1994 period to 44% in the 2005–2009 time frame, whilst the percentage of articles produced with no collaboration decreased from 45.9% to 25% between these two periods. Domestic collaboration remained fairly constant at about 30% of articles (Figure 2). Foreign institutions collaborating were from 40 countries (Table 4), with Australia ( $n = 31$ ), the USA ( $n = 27$ ) and the Netherlands ( $n = 20$ ) being major partners. Countries with more than 300 citations included those from South Africa ( $n = 4453$ ), followed by the USA ( $n = 678$ ), Spain ( $n = 388$ ), Belgium ( $n = 351$ ), the Netherlands ( $n = 337$ ) and Australia ( $n = 305$ ).

**TABLE 1:** Number of viticulture and oenology articles published during 1990–2009 by journal, journal impact factor and country of publication.

| Journal title  | Articles  |           |           |           | 2009 Impact factor | Country |              |
|--|-----------|-----------|-----------|-----------|--------------------|---------|--------------|
|  | 1990–1994 | 1995–1999 | 2000–2004 | 2005–2009 |                    |         |              |
| South African Journal of Enology and Viticulture         | -         | -         | -         | 34        | 34                 | 0.314   | South Africa |
| American Journal of Enology and Viticulture              | 10        | 2         | 2         | 2         | 16                 | 1.171   | USA          |
| Journal of Agricultural and Food Chemistry               | -         | -         | 6         | 10        | 16                 | 2.469   | USA          |
| Vitis  | 1         | 6         | 3         | 1         | 11                 | 0.800   | Germany      |
| South African Journal of Science                         | -         | -         | 5         | 6         | 11                 | 0.506   | South Africa |
| Australasian Plant Pathology                             | -         | -         | 5         | 6         | 11                 | 0.943   | Australia    |
| Plant Disease  | 1         | 3         | 3         | 1         | 8                  | 2.121   | USA          |
| Yeast  | 1         | 3         | 2         | 1         | 7                  | 1.805   | England      |
| African Entomology                                       | -         | 1         | 1         | 5         | 7                  | 0.420   | South Africa |
| Mycologia  | -         | -         | 3         | 4         | 7                  | 1.587   | USA          |
| International Journal of Food Microbiology               | -         | -         | 4         | 2         | 6                  | 3.011   | Netherlands  |
| Journal International des Sciences de la Vigne et du Vin | -         | -         | -         | 5         | 5                  | 0.771   | France       |
| European Journal of Plant Pathology                      | -         | -         | 2         | 3         | 5                  | 1.931   | Netherlands  |
| Journal of Applied Microbiology                          | -         | -         | 2         | 3         | 5                  | 2.098   | England      |
| Applied and Environmental Microbiology                   | -         | -         | 3         | 2         | 5                  | 3.686   | USA          |
| Water SA   | 1         | 1         | 3         | -         | 5                  | 0.911   | South Africa |
| Annals of Microbiology                                   | -         | -         | 3         | 2         | 5                  | 0.358   | Italy        |
| Journal of Chromatography A                              | -         | -         | 3         | 1         | 4                  | 4.101   | Netherlands  |
| Studies in Mycology                                      | -         | -         | -         | 4         | 4                  | 6.349   | Netherlands  |
| Australian Journal of Grape and Wine Research            | -         | -         | 1         | 3         | 4                  | 1.872   | Australia    |
| FEMS Yeast Research                                      | -         | -         | 2         | 2         | 4                  | 1.785   | Netherlands  |
| Applied Microbiology and Biotechnology                   | 1         | -         | 1         | 2         | 4                  | 2.896   | USA          |

**TABLE 2:** Authors with five or more published viticulture and oenology articles and citations during 1990–2009.

| Author                   | Articles  |           |           |           |       | Citations |           |           |           |       |
|--------------------------|-----------|-----------|-----------|-----------|-------|-----------|-----------|-----------|-----------|-------|
|                          | 1990–1994 | 1995–1999 | 2000–2004 | 2005–2009 | Total | 1990–1994 | 1995–1999 | 2000–2004 | 2005–2009 | Total |
| Pretorius, Isak S        | 3         | 3         | 21        | 13        | 40    | 72        | 82        | 609       | 93        | 856   |
| Crous, Pedro W           | -         | -         | 9         | 10        | 19    | -         | -         | 202       | 77        | 279   |
| Van Rensburg, Pierre     | 1         | 1         | 9         | 7         | 18    | 24        | 42        | 124       | 19        | 209   |
| Bauer, Florian F         | -         | 3         | 3         | 12        | 18    | -         | 126       | 94        | 62        | 282   |
| Goszczynski, Dariusz E   | -         | 4         | 4         | 8         | 16    | -         | 73        | 45        | 52        | 170   |
| Fourie, Paul H           | -         | -         | 5         | 10        | 15    | -         | -         | 96        | 71        | 167   |
| Otero, Ricardo R Cordero | -         | -         | 7         | 7         | 14    | -         | -         | 93        | 30        | 123   |
| Lambrechts, Marius G     | -         | -         | 10        | 4         | 14    | -         | -         | 233       | 40        | 273   |
| Du Toit, Maret           | -         | 1         | 3         | 10        | 14    | -         | 32        | 52        | 12        | 96    |
| Hunter, JJ               | 4         | 5         | 1         | 2         | 12    | 76        | 63        | 4         | -         | 143   |
| Halleen, Francois        | -         | -         | 6         | 6         | 12    | -         | -         | 163       | 57        | 220   |
| Van Vuuren, Hennie JJ    | 4         | 4         | 2         | 1         | 11    | 151       | 130       | 22        | 18        | 321   |
| Dicks, Leon MT           | 2         | 2         | 3         | 4         | 11    | 62        | 44        | 44        | 20        | 170   |
| Sandra, Pat              | -         | -         | 7         | 3         | 10    | -         | -         | 254       | 15        | 269   |
| De Villiers, Andre       | -         | -         | 5         | 4         | 9     | -         | -         | 79        | 15        | 94    |
| Viljoen-Bloom, M         | 1         | 3         | 5         | -         | 9     | 31        | 90        | 68        | -         | 189   |
| Mostert, Lizel           | -         | -         | 4         | 5         | 9     | -         | -         | 75        | 45        | 120   |
| Du Toit, Wessel Johannes | -         | -         | 2         | 6         | 8     | -         | -         | 27        | 23        | 50    |
| Vivier, Melane A         | -         | 1         | 4         | 3         | 8     | -         | 32        | 101       | 19        | 152   |
| Groenewald, Johannes Z   | -         | -         | 3         | 5         | 8     | -         | -         | 79        | 51        | 130   |
| Volschenk, Heinrich      | -         | 2         | 3         | 2         | 7     | -         | 86        | 39        | 20        | 145   |
| Holz, G                  | -         | 4         | 3         | -         | 7     | -         | 56        | 29        | -         | 85    |
| Joubert, E               | -         | -         | 1         | 6         | 7     | -         | -         | 45        | 47        | 92    |
| Archer, E                | -         | -         | -         | 7         | 7     | -         | -         | -         | 10        | 10    |
| Crouch, Andrew M         | -         | -         | 3         | 4         | 7     | -         | -         | 30        | 25        | 55    |
| Lynen, Frederic          | -         | -         | 3         | 3         | 6     | -         | -         | 30        | 15        | 45    |
| Botha, Frederik C        | -         | -         | 4         | 2         | 6     | -         | -         | 15        | 2         | 17    |
| Subden, RE               | 1         | 4         | 1         | -         | 6     | 31        | 130       | 13        | -         | 174   |
| Wingfield, Michael J     | -         | -         | 4         | 2         | 6     | -         | -         | 46        | 24        | 70    |
| Manley, M                | -         | -         | 2         | 4         | 6     | -         | -         | 72        | 29        | 101   |
| Nieuwoudt, Helene H      | -         | -         | 1         | 5         | 6     | -         | -         | 27        | 15        | 42    |
| Blackhurst, DM           | -         | -         | -         | 5         | 5     | -         | -         | -         | 4         | 4     |
| Britz, TJ                | -         | 1         | 1         | 3         | 5     | -         | 3         | 22        | 8         | 33    |
| Burger, AL               | -         | -         | 4         | 1         | 5     | -         | -         | 15        | 0         | 15    |
| Bauer, Rolene            | -         | -         | 2         | 3         | 5     | -         | -         | 26        | 23        | 49    |
| Burgess, Joanna E        | -         | -         | -         | 5         | 5     | -         | -         | -         | 10        | 10    |
| Van Zyl, Willem H        | 1         | 1         | -         | 3         | 5     | 24        | 42        | -         | 13        | 79    |
| Ekama, GA                | 1         | -         | 4         | -         | 5     | 4         | -         | 55        | -         | 59    |
| Witthuhn, R Corli        | -         | -         | 1         | 4         | 5     | -         | -         | 22        | 9         | 31    |
| McLeod, Adele            | -         | -         | -         | 5         | 5     | -         | -         | -         | 31        | 31    |
| Wentzel, MC              | 1         | -         | 4         | -         | 5     | 4         | -         | 55        | -         | 59    |
| De Beer, D               | -         | -         | 1         | 4         | 5     | -         | -         | 45        | 29        | 74    |
| Ruffner, HP              | 1         | 3         | 1         | -         | 5     | 17        | 60        | 4         | -         | 81    |

A threshold of three articles co-authored between authors has been used for a representation of networks of collaboration. Using this threshold, 18 different groups were drawn with different components or numbers of authors in each group (Figure 3). The largest group had 21 components and the central author was Pretorius, who established co-authorship relations with eight other authors, amongst them Van Rensburg (with whom he published 14 articles), and Otero and Lambrechts, with whom he published 10 articles each. Otero also occupied a prominent, central position and had collaborations with seven other authors, including Bauer, Subden and Van Vuuren, who each had five other collaborators. Two groups of seven components each were

also found; these central authors were Goszczynski and Crous, respectively. Other smaller groups were also found: one group of six authors, two groups of five authors, five groups of three authors and seven groups of two authors.

Stellenbosch University was situated in a central position in the network where a threshold of two co-authored articles was used (Figure 4), with its most regular collaborations having been with the Agricultural Research Council (39 articles), the Australian Wine Research Institute (19 articles) and Distell Group Limited South Africa (16 articles). Other centres that also occupied a central position, although less strongly, were the University of Pretoria, the Australian

**TABLE 3:** Institutions that published viticulture and oenology articles and received citations during 1990–2009.

| Institution   | Articles  |           |           |           |       | Citations |           |           |           |       |
|---|-----------|-----------|-----------|-----------|-------|-----------|-----------|-----------|-----------|-------|
|   | 1990–1994 | 1995–1999 | 2000–2004 | 2005–2009 | Total | 1990–1994 | 1995–1999 | 2000–2004 | 2005–2009 | Total |
| Stellenbosch University (South Africa)  | 11        | 18        | 64        | 126       | 219   | 263       | 335       | 1499      | 495       | 2592  |
| Agricultural Research Council (Infruitec-Nietvoorbij, Stellenbosch, South Africa)           | -         | 2         | 15        | 32        | 49    | -         | 32        | 299       | 123       | 454   |
| University of Cape Town (South Africa)  | 3         | 7         | 7         | 15        | 32    | 31        | 43        | 121       | 90        | 285   |
| University of Pretoria (South Africa)   | 3         | 2         | 8         | 18        | 31    | 19        | 13        | 148       | 74        | 254   |
| Agricultural Research Council (Plant Protection Research Institute, Pretoria, South Africa) | -         | 7         | 8         | 8         | 23    | -         | 82        | 74        | 60        | 216   |
| Australian Wine Research Institute (Australia)  | -         | -         | 6         | 13        | 19    | -         | -         | 102       | 91        | 193   |
| Distell (South Africa)  | -         | -         | 6         | 10        | 16    | -         | -         | 64        | 49        | 113   |
| Institute for Viticulture & Oenology (Nietvoorbij, South Africa)                            | 8         | 5         | -         | 2         | 15    | 147       | 40        | -         | 8         | 195   |
| Centraalbureau voor Schimmelcultures (the Netherlands)                                      | -         | -         | 5         | 8         | 13    | -         | -         | 147       | 65        | 212   |
| University of Natal (South Africa)†   | 3         | 3         | 4         | 1         | 11    | 54        | 38        | 37        | -         | 129   |
| Rhodes University (South Africa)  | -         | -         | 2         | 9         | 11    | -         | -         | 14        | 22        | 36    |
| University of the Witwatersrand (South Africa)  | -         | 1         | 4         | 5         | 10    | -         | 12        | 46        | 37        | 95    |
| University of Guelph (Canada)   | 1         | 4         | 1         | 4         | 10    | 31        | 130       | 13        | 39        | 213   |
| University of KwaZulu-Natal (South Africa)  | -         | -         | 1         | 8         | 9     | -         | -         | 8         | 38        | 46    |
| Cape Peninsula University of Technology (South Africa)                                      | -         | -         | -         | 9         | 9     | -         | -         | -         | 33        | 33    |
| Ghent University (Belgium)‡   | -         | -         | 4         | 2         | 6     | -         | -         | 224       | 35        | 259   |
| Agricultural Research Service (United States Department of Agricultural, USA)               | 1         | -         | -         | 4         | 5     | 4         | -         | -         | 39        | 43    |
| Universidad de Castilla-La Mancha (Spain)   | -         | -         | 2         | 3         | 5     | -         | -         | 20        | 17        | 37    |
| University of the Western Cape (South Africa)   | 1         | 1         | -         | 3         | 5     | 42        | 6         | -         | 1         | 49    |
| University of the Orange Free State (South Africa)  | 1         | 2         | -         | 2         | 5     | 33        | 16        | -         | 19        | 68    |
| University of Durban Westville (South Africa)†  | -         | 2         | 3         | -         | 5     | -         | 9         | 21        | -         | 30    |
| Cornell University (USA)  | 1         | 1         | -         | 2         | 4     | 4         | 53        | -         | 30        | 87    |
| Consejo Superior de Investigaciones Cientificas (Spain)                                     | -         | -         | 2         | 2         | 4     | -         | -         | 336       | 6         | 342   |
| Australian Commonwealth Scientific and Research Organization (Australia)                    | -         | -         | 1         | 3         | 4     | -         | -         | 40        | 13        | 53    |
| Universität Zürich (Switzerland)  | 1         | 3         | -         | -         | 4     | 17        | 60        | -         | -         | 77    |
| Tshwane University of Technology (South Africa)   | -         | -         | -         | 4         | 4     | -         | -         | -         | 11        | 11    |

†. On 1 January 2004, the University of Natal merged with the University of Durban-Westville to form the University of KwaZulu-Natal.

‡. In 1991, Ghent University was granted major autonomy and changed its name from State University of Ghent to Ghent University.

Wine Research Institute, Distell Group Limited South Africa, Cape Peninsula University of Technology (Cape Town, South Africa), Dipartimento Colture Arboree (Palermo, Italy) and University of Guelph (Ontario, Canada). South Africa collaborated with Australia on 31 articles, with the USA on 27 articles and with the Netherlands on 20 articles (Figure 5).

### Most cited articles

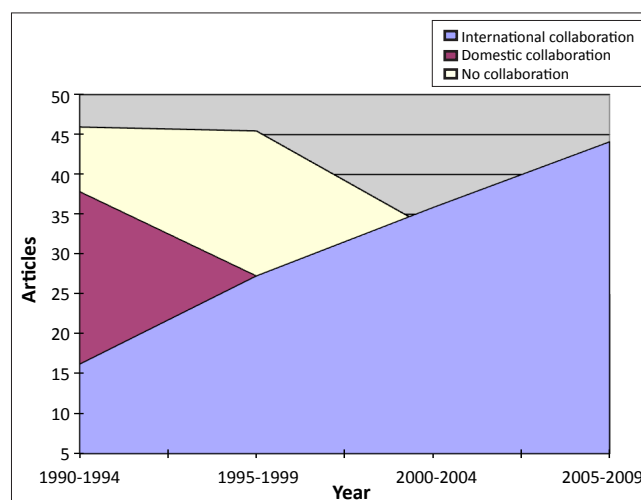
The most cited article was that of Gil and colleagues published in 2000 in the *Journal of Agricultural and Food Chemistry*. This article was cited 290 times (Table 5). The only other article to have been cited more than 200 times was that of Pretorius published in the same year in the journal *Yeast*, with 218 citations.

## Discussion

Viticulture and oenology is a growing field of scientific research. Bibliometric methods allow the characterisation of the size, growth and distribution of scientific publications, identifying the most productive, influential and prestigious authors and institutions. A co-authorship network

analysis offers a perspective on research groups and the position of the most outstanding researchers.

There were four major limitations in this study. Firstly, bibliographic data in the SCI database are not standardised, which leads to the same author or institutional affiliation



**FIGURE 2:** Changes in domestic and international collaboration of South African viticulture and oenology institutions between 1990 and 2009.



**TABLE 4:** The number of viticulture and oenology articles and citations during 1990–2009, by country.

| Country                   | Articles  |           |           |           |       | Citations |           |           |           |       |
|---------------------------|-----------|-----------|-----------|-----------|-------|-----------|-----------|-----------|-----------|-------|
|                           | 1990–1994 | 1995–1999 | 2000–2004 | 2005–2009 | Total | 1990–1994 | 1995–1999 | 2000–2004 | 2005–2009 | Total |
| South Africa              | 37        | 55        | 106       | 220       | 418   | 561       | 659       | 2313      | 920       | 4453  |
| Australia                 | 1         | -         | 8         | 22        | 31    | 4         | -         | 149       | 152       | 305   |
| USA                       | 2         | 4         | 5         | 16        | 27    | 38        | 155       | 336       | 149       | 678   |
| Netherlands               | -         | -         | 7         | 13        | 20    | -         | -         | 228       | 109       | 337   |
| Canada                    | 1         | 4         | 3         | 7         | 15    | 31        | 130       | 68        | 64        | 293   |
| France                    | 1         | 2         | 1         | 10        | 14    | 4         | 86        | 46        | 61        | 197   |
| Belgium                   | -         | -         | 7         | 6         | 13    | -         | -         | 308       | 43        | 351   |
| Spain                     | -         | -         | 4         | 9         | 13    | -         | -         | 356       | 32        | 388   |
| Switzerland               | 3         | 3         | 1         | 3         | 10    | 23        | 60        | 4         | 17        | 104   |
| UK                        | -         | 2         | 1         | 5         | 8     | -         | 11        | 7         | 10        | 28    |
| Germany                   | 1         | 1         | -         | 5         | 7     | 17        | 3         | -         | 26        | 46    |
| Italy                     | 1         | 2         | 1         | 3         | 7     | 4         | 41        | 49        | 1         | 95    |
| Israel                    | 1         | -         | 1         | 3         | 5     | 4         | -         | 15        | 11        | 30    |
| Japan                     | -         | -         | 1         | 2         | 3     | -         | -         | 40        | 1         | 41    |
| Slovakia                  | -         | -         | 1         | 2         | 3     | -         | -         | 31        | 15        | 46    |
| Slovenia                  | -         | -         | -         | 2         | 2     | -         | -         | -         | 10        | 10    |
| Peoples Republic of China | -         | -         | -         | 2         | 2     | -         | -         | -         | 5         | 5     |
| Norway                    | -         | -         | -         | 2         | 2     | -         | -         | -         | 9         | 9     |
| Nigeria                   | -         | -         | -         | 2         | 2     | -         | -         | -         | 1         | 1     |
| Zimbabwe                  | -         | -         | 2         | -         | 2     | -         | -         | 16        | -         | 16    |
| Croatia                   | -         | -         | 2         | -         | 2     | -         | -         | 43        | -         | 43    |
| Sweden                    | -         | -         | 1         | 1         | 2     | -         | -         | 31        | -         | 31    |
| Austria                   | -         | 1         | -         | 1         | 2     | -         | 35        | -         | -         | 35    |
| Portugal                  | -         | -         | 1         | 1         | 2     | -         | -         | 20        | 10        | 30    |
| Czech Republic            | -         | -         | -         | 1         | 1     | -         | -         | -         | 1         | 1     |
| Byelarus                  | -         | -         | -         | 1         | 1     | -         | -         | -         | 1         | 1     |
| Brazil                    | -         | -         | -         | 1         | 1     | -         | -         | -         | 5         | 5     |
| Denmark                   | -         | -         | -         | 1         | 1     | -         | -         | -         | 4         | 4     |
| Finland                   | -         | -         | 1         | -         | 1     | -         | -         | 74        | -         | 74    |
| Hungary                   | -         | -         | -         | 1         | 1     | -         | -         | -         | 1         | 1     |
| Iran                      | -         | -         | -         | 1         | 1     | -         | -         | -         | 4         | 4     |
| Argentina                 | -         | -         | -         | 1         | 1     | -         | -         | -         | 1         | 1     |
| New Zealand               | -         | -         | -         | 1         | 1     | -         | -         | -         | -         | 0     |
| Romania                   | -         | -         | -         | 1         | 1     | -         | -         | -         | 1         | 1     |
| South Korea               | -         | -         | -         | 1         | 1     | -         | -         | -         | 4         | 4     |
| Sri Lanka                 | -         | -         | -         | 1         | 1     | -         | -         | -         | 11        | 11    |
| Thailand                  | -         | 1         | -         | -         | 1     | -         | 4         | -         | -         | 4     |
| Uruguay                   | -         | -         | -         | 1         | 1     | -         | -         | -         | -         | 0     |
| Venezuela                 | -         | -         | -         | 1         | 1     | -         | -         | -         | 17        | 17    |
| Namibia                   | -         | -         | -         | 1         | 1     | -         | -         | -         | 4         | 4     |

**TABLE 5:** Most cited viticulture and oenology articles published between 1990 and 2009.

| Authors   | Year of publication | Article title   | Source  | Number of citations |
|---|---------------------|---|---|---------------------|
| Gil MI, Tomas-Barberan FA, Hess-Pierce B, Holcroft DM, Kadewr AA  | 2000                | Antioxidant activity of pomegranate juice and its relationship with phenolic composition and processing   | Journal of Agricultural and Food Chemistry 48:4581–4589 | 290                 |
| Pretorius IS  | 2000                | Tailoring wine yeast for the new millennium: Novel approaches to the ancient art of winemaking  | Yeast 16:675–729  | 218                 |
| Sandra P, Tienpont B, Vercammen J, Tredoux A, Sandra T            | 2001                | Stir bar sorptive extraction applied to the determination of dicarboximide fungicides in wine   | Journal of Chromatography A 928:117–126                 | 98                  |
| Sandra P, Tienpont B, David F                                     | 2003                | Multi-residue screening of pesticides in vegetables, fruits and baby food by stir bar sorptive extraction-thermal desorption-capillary gas chromatography-mass spectrometry | Journal of Chromatography A 1000:299–309                | 77                  |
| Van der Gaag MS, Ubbink JB, Sillanauke P, Nikkari S, Hendriks HFJ | 2000                | Effect of consumption of red wine, spirits, and beer on serum homocysteine  | Lancet 35:1522–1522                                     | 74                  |
| Lilly M, Lambrechts MG, Pretorius IS                              | 2000                | Effect of increased yeast alcohol acetyltransferase activity on flavor profiles of wine and distillates   | Applied and Environmental Microbiology 66:744–753       | 74                  |
| Volschenk H, Viljoen-Bloom M, Grobler J, Petzold B, Bauer FF      | 1997                | Engineering pathways for malate degradation in <i>Saccharomyces cerevisiae</i>  | Nature Biotechnology 15:253–257                         | 62                  |
| Van Vuuren HJJ, Dicks LMT   | 1993                | <i>Leuconostoc oenos</i> – A review   | American Journal of Enology and Viticulture 44:99–112   | 55                  |
| Zhu HY, Ling KS, Goszczynski DE, McFerson JR, Gonsalves D         | 1998                | Nucleotide sequence and genome organization of grapevine leafroll-associated virus-2 are similar to beet yellows virus, the closterovirus type member                       | Journal of General Virology 79:1289–1298                | 53                  |

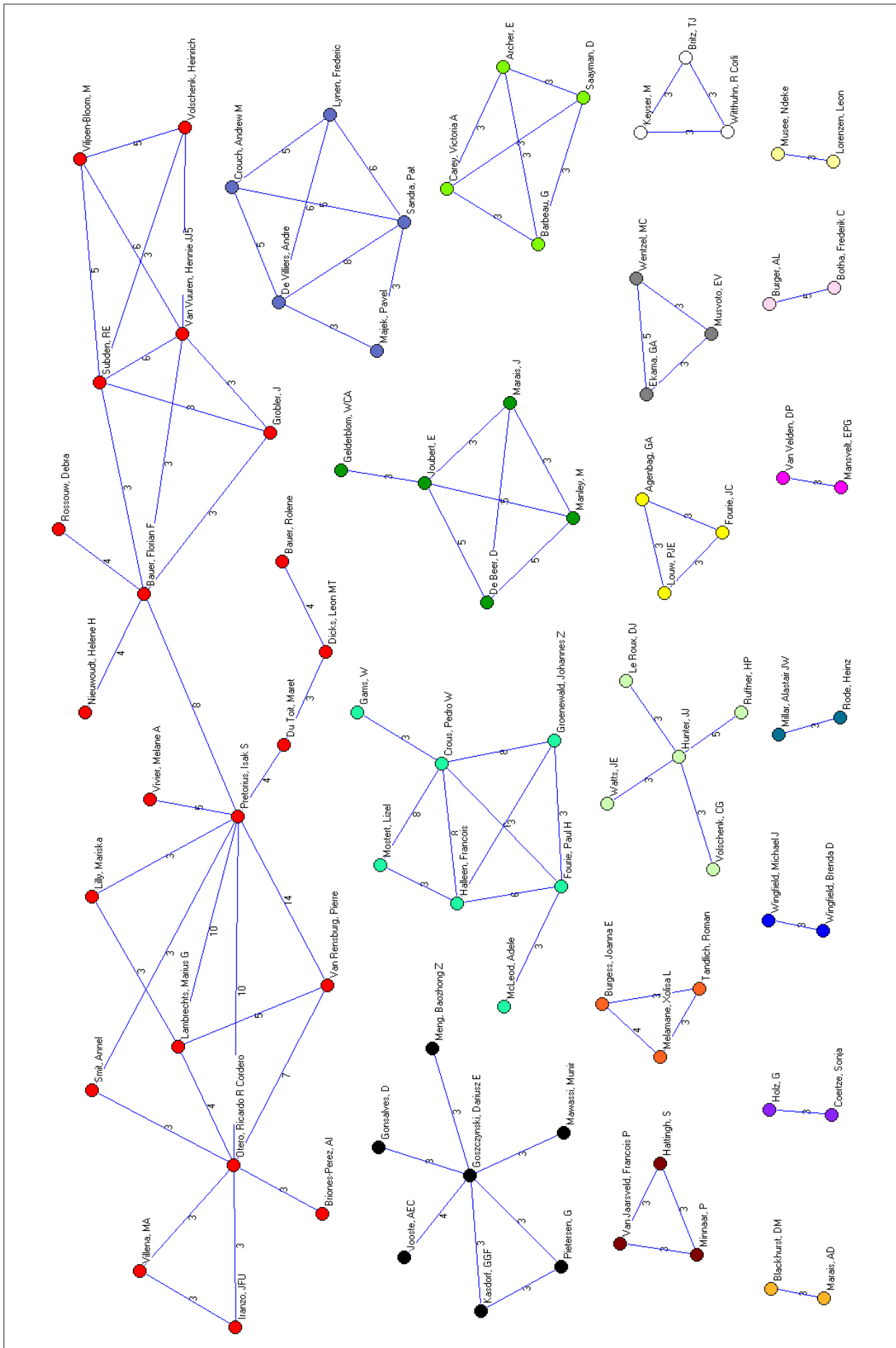


FIGURE 3: Networks of authors of viticulture and oenology articles, created by using a threshold of three or more articles co-authored.

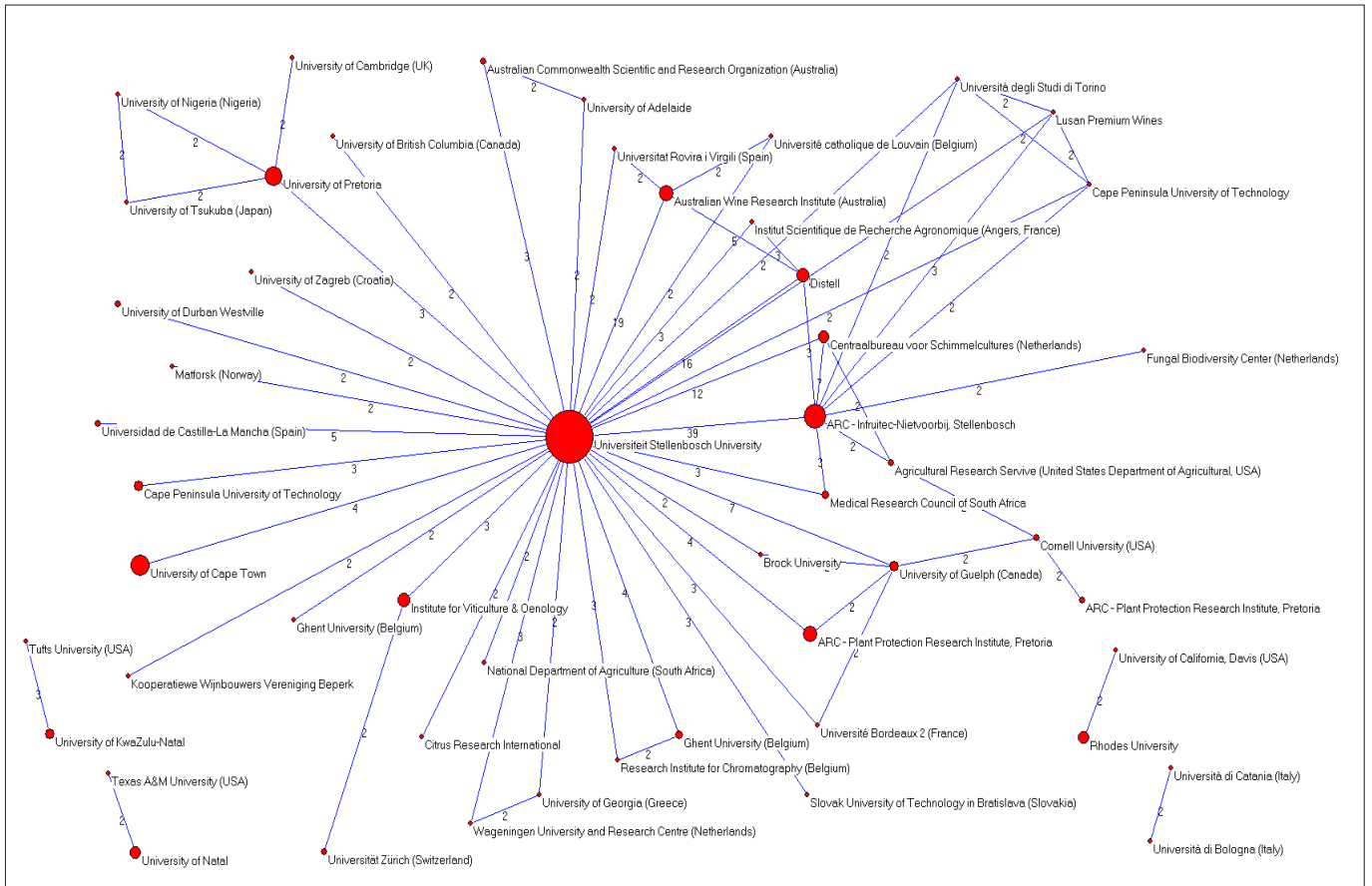


FIGURE 4: Networks of institutions publishing viticulture and oenology research, created by using a threshold of two or more collaborative articles.

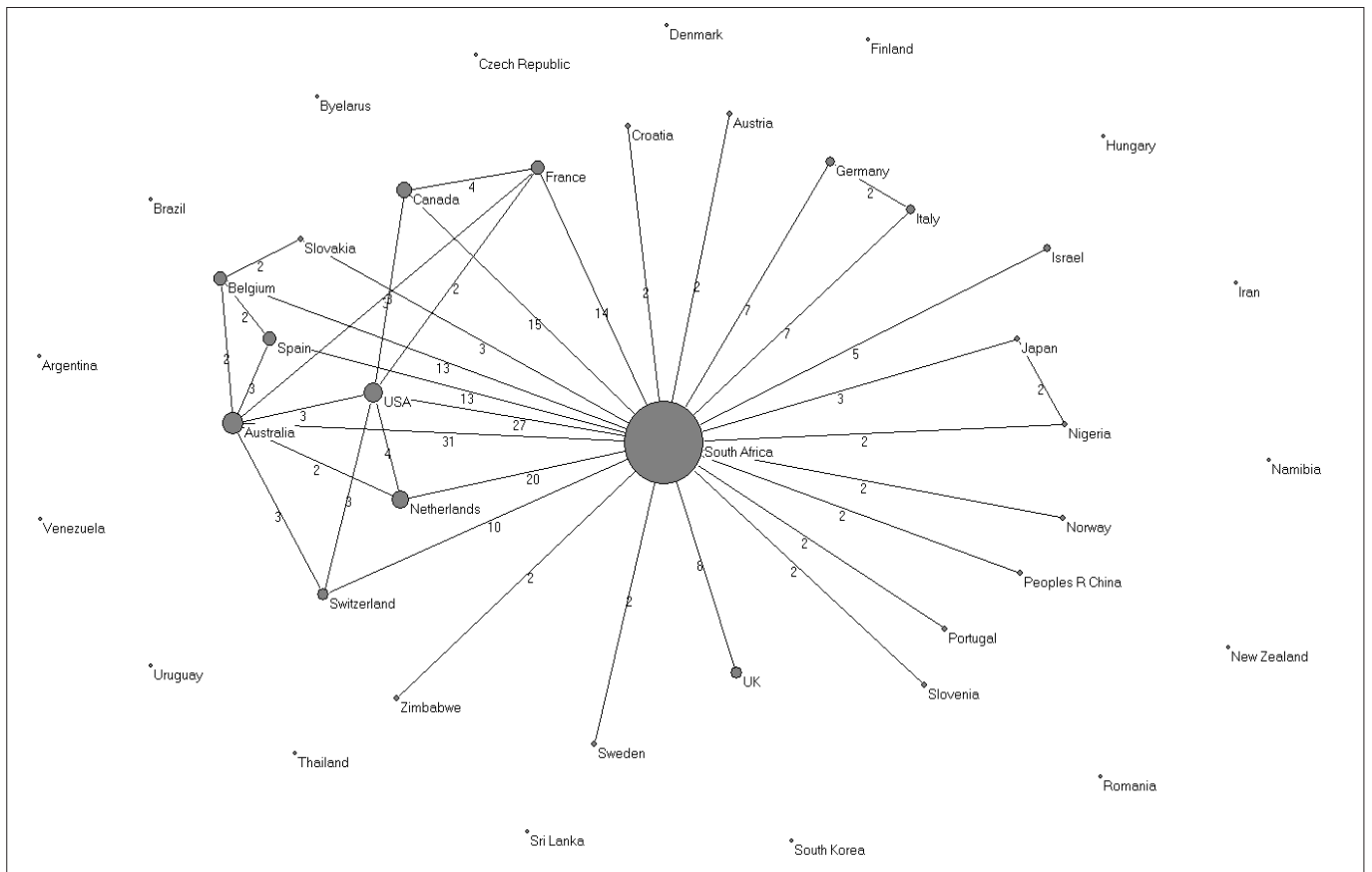


FIGURE 5: Networks of countries of origin of viticulture and oenology articles, created by using a threshold of two or more collaborative articles.





appearing under different names. To unify these variants, a careful manual standardisation was performed, in which directories of universities and research centres, as well as their respective websites, were checked.

Secondly, the SCI database does not include all the published scientific literature on viticulture and oenology, and other bibliographic databases and additional data gathering from local South African science journals could have been used as an alternative or supplement, as pointed out by Tijssen et al.<sup>37</sup> However, the use of SCI as a source of information in this article had the following advantages:

1. It provided all the authors who signed the articles and all their institutional affiliations, allowing us to obtain indicators of collaboration between authors and institutions.
2. It provided the number of citations the articles had received and, therefore, determined the number of citations of their authors and institutions. Moreover, the database provided the JCR impact factor of the journals – information which is not present in other databases.
3. SCI is a source widely used in studies examining the scientific activity in the various fields of science and technology because it includes the highest impact journals and helps to achieve the objective of focusing the analyses on the most relevant authors and institutions, identifying and characterising the production and scientific impact of the research front in the analysed area.

In order to identify the gap in data collection when using SCI as a sole source of information, we analysed three annual research reports of the Department of Viticulture and Enology at Stellenbosch University. Of the 42 articles published from 2007 to 2009, 15 (36%) were published in international peer-reviewed journals and 27 (64%) in local journals, most of which were published in Afrikaans in the journals *Wynboer* and *SA Fruit Journal*.

Thirdly, the social network analysis based on co-authorship of scientific articles has only recently been studied.<sup>38</sup> For this reason, we have not found similar works in the scientific literature that have analysed the research and social networks of viticulture and oenology from the point of view of publications.

Lastly, the identification of the articles used in this study, the authors and partnerships, did not allow us to investigate in more detail the contribution of each to the advancement and dissemination of knowledge, beyond their citation in later publications.

Despite the aforementioned limitations, this work identified the most productive authors and institutions in the field of South African viticulture and oenology during the period investigated. The composition of research groups that can be considered to be at the forefront of research in this area were also identified.<sup>28</sup>

Two distinct periods in the annual evolution of the number of published articles were observed: one from 1990 to early

2004, with a moderate production of between 10 and 20 articles per year, and a second from 2005 to 2009, in which there was a notable growth to an average of 44 articles per year. A reason for this increase could be the inclusion of the *South African Journal of Enology and Viticulture* in SCI in 2005. (This journal has been published in English since 1980 by the South African Society for Enology and Viticulture.) Other reasons could also be the increasing number of South African journals included in SCI<sup>19</sup> – from 19 in 2001 to 29 in 2009 – as well as an increase in the number of articles published in other journals such as *American Journal of Enology and Viticulture*, *South African Journal of Science* and *African Entomology*. However, there remains a poor coverage of South African journals in international bibliographic databases (in particular SCI). Consequently, higher-quality articles originated in South Africa are usually published in American or European journals. These journals have a privileged position in the mainstream of science and they are able to attract the leading scientists' articles. The small size of the South African scientific community and their position at the periphery of science are other factors that may contribute to the low impact factors of South African journals. The growth of research in viticulture and oenology in South Africa has also been observed in other scientific areas. Molatudi et al.<sup>16</sup> found that 65% of South African literature in bioinformatics since 1990 was published in the period 2001–2006. In Medicine, the number of articles doubled between 1975 and 2005,<sup>15</sup> and in Engineering, the proliferation in the number of articles was almost seven-fold for the same period.<sup>17</sup> For HIV and AIDS research, the number of publications increased five-fold between 1996 and 2006.<sup>18</sup> Moreover, the importance of South African scientific output in the area of viticulture and oenology has been highlighted by Glänzel and Veugelers<sup>34</sup>, who ranked South Africa in 15th place in terms of productivity.

The distribution of journal articles can give an idea of the areas covered in the current multidisciplinary viticulture and oenology fields, as many researchers publish in journals specific to other areas such as Food Science and Technology (e.g. *Journal of Agricultural and Food Chemistry* and *International Journal of Food Microbiology*), general purpose (*South African Journal of Science*), Plant Sciences (*Australasian Plant Pathology*, *Plant Disease* and *European Journal of Plant Pathology*), Microbiology and Biotechnology (*Yeast*, *International Journal of Food Microbiology* and *Journal of Applied Microbiology*). This diversity of subject areas should alert researchers seeking information on viticulture and oenology to expand their search to journals in related areas and even general purpose journals.<sup>39</sup>

The most prolific author, I.S. Pretorius, is currently a researcher at the Australian Wine Research Institute (Adelaide, Australia). Researchers at this institution collaborate extensively with many South African researchers, including P. van Rensburg and F.F. Bauer from the Institute of Wine Biotechnology at Stellenbosch University. The second most prolific author, P.W. Crous, is a researcher at Centraalbureau



for Schimmelcultures (Utrecht, the Netherlands) and also works closely with counterparts in the Department of Plant Pathology at Stellenbosch University. The presence of foreign authors in South African research can be regarded as an objective indicator of the level of international cooperation that keeps the country in the forefront of this field. It is noteworthy that both Pretorius and Crous are South Africans who, before emigrating, held positions at Stellenbosch University.

Stellenbosch University is leading research in viticulture and oenology through the Department of Viticulture and Oenology ([http://academic.sun.ac.za/viti\\_oenol/](http://academic.sun.ac.za/viti_oenol/)). Tuition has been offered at Stellenbosch University since the 1880s and the university has a long history of engagement with vine and wine sciences as well as a close association with the South African grape and wine industries. The Institute for Wine Biotechnology was established in 1995 by a team of academics and researchers and was integrated into the Department of Viticulture and Oenology of Stellenbosch University in 2003. The involvement of many foreign institutions (as can be seen in Table 3), especially from Australia, Holland, France and Spain, is therefore not surprising, because the Department maintains contact and active research collaborations with many national and international universities and research organisations. These collaborations involve the establishment of agreements for the exchange of students and foreign researchers, as well as many collaborative research projects. An example of this dynamic in the field of viticulture and oenology is the agreement between the European Union and South Africa through the Erasmus Mundus Vintage International Masters of Science programme (<http://www.vintagemaster.com>). Erasmus Mundus is a cooperation and mobility programme in the field of higher education that aims to enhance the quality of European higher education and to promote dialogue and understanding between people and cultures through cooperation with developing countries. These agreements enable students, teachers and researchers from countries within the European Union and South Africa to participate in scientific programmes and, thereby, increase their mobility. The promotion of work periods in foreign research centres is considered crucial to promote the internationalisation of science in any country.<sup>40</sup> As evidenced in this study, there has been a steady increase in international collaboration in the viticulture and oenology area, which also is consistent with the data provided by Sooryamoorthy<sup>41</sup> for all areas of research in South Africa.

Social network analysis identified the main groups of researchers who had scientific collaborations and whom could be considered at the forefront of their areas,<sup>42</sup> beyond the formal structures that make up the research institutes and departments of universities and other research institutions. Knowledge of these structures has several advantages for researchers. In the first instance, it provides them with reliable information about existing groups that maintain a high-level research activity – information that provides the possibility of expanding their circle of contacts and participation in

discussion forums, and increases the exchange of ideas on relevant topics, as well as allows linking and integration into any of the identified networks.<sup>30,31,43</sup> Additionally, such information enables researchers to know which institutions work together and which occupy more central roles within the network, which is valuable information when deciding on which institutions could be appropriate to establish collaborative arrangements with, or to conduct metacentre studies. According to Barabasi and Albert<sup>44</sup>, the nodes of a network of a collaboration that already have many connections will be preferentially chosen by new research groups to initiate a scientific collaboration, and a group rich in connections (or collaborations) will increase their influence more rapidly than those with fewer.<sup>43</sup> Moreover, the identification of groups with similar scientific interests and research lines allows increasing effectiveness in research, as it prevents duplication of experiments.<sup>41,44,45,46,47</sup> The existence of a group consisting of a small number of researchers with little or no integration with other groups of the same scientific field can be explained by that group possibly being at the beginning of its research activity period.<sup>48,49</sup> However, the researchers with the largest number of publications are not always at the research front, especially in the case of an extended time window, in this case 20 years (1990–2009), because many of the prolific authors are likely to become heads of departments or lab directors. In this case, we found that 7 of the 14 authors with more than 10 articles were last author on more than 50% of their articles.

## Conclusions

In conclusion, this study provides indicators to assess the state of South African research in viticulture and oenology and its evolution over the past 20 years, using articles published in international impact scientific journals. In short, we have identified a significant growth in South African research in recent years, with a high degree of internationalisation and a constant level of domestic collaboration. The research is organised mainly around research centres in the country, primarily Stellenbosch University, with the main vehicle for dissemination of this scientific activity being the *South African Journal of Enology and Viticulture*. The patterns and trends of South African research in this field are similar to other countries from the southern hemisphere, notably Chile,<sup>50</sup> who has a wine industry that is in many ways in a similar socio-economic position to that of the South African industry.

Future work in this area could identify newly emerging groups and observe the temporal evolution of the groups already recognised, as well as the existence of authors or institutions that remain on the periphery or are isolated from others.<sup>31</sup>

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## Competing interests

We declare that we have no financial or personal relationships which may have inappropriately influenced us in writing this article.

## Authors' contributions

R.A.-B. was the project leader and wrote the manuscript. J.L.A.-T. searched and reviewed the literature. J.L.A. was responsible for the information concerning viticulture and oenology. G.G.A. was responsible for the statistical treatment. A.F.S. was responsible for the bibliometric analysis. W.d.T. made conceptual contributions and reviewed the manuscript.

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