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Bibliometric analysis of blueberry (*Vaccinium corymbosum* L.) research publications based on Web of Science

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Abstract

This study aimed to identify and analyze the 3,872 article and review type papers of blueberry research based on Web of Science. Papers mainly written in English (3,769, 97.34%), were from 10,102 authors, 83 countries or territories, 2,033 organizations and published in 770 Journals and three book series. The top five Journals were *HortScience* (278, 7.18%), *Journal of the American Society for Horticultural Science* (272, 7.024%), *Journal of Agricultural and Food Chemistry* (116, 2.996%), *Journal of Economic Entomology* (97, 2.505%), *Food Chemistry* (92, 2.376%). The top five countries and regions were USA, Peoples R China, Canada, Chile and Brazil. The six most paper contributed organizations were USDA ARS, University of Florida, Michigan State University, University of Georgia, Agriculture and Agri-Food Canada, and University of Maine. The top five authors were Hancock, James F.; Rowland, Lisa J.; Ehlenfeldt, Mark K.; Lyrene, Paul M.; and Strik, Bernadine C. All keywords of the blueberry research based on Web of Science were separated into seven clusters for different research topics. This review could provide a valuable guide for designing future studies. This work is also useful for student identifying graduate schools and researchers selecting journals.

Keywords: bibliometric analysis; blueberry (*Vaccinium corymbosum* L.);VOSviewer; Web of Science.

Practical Application: Bibliometric analysis of blueberry research.

1 Introduction

The blueberry (*Vaccinium corymbosum*) is a desired fruit with low calorific value and source of potassium, iron, and calcium. Blueberries, given their pleasant taste and great abundance in beneficial phytochemicals, have gained public interest all over the world and emerged as a major fruit crop. The rapid and extensive increase in its cultivation is related, in-part, to health-promoting, nutraceutical characteristics associated with blueberry consumption (Doyle et al., 2021). Blueberries are consumed as fresh fruits, but a large fraction of total production is processed for production of juice and wine (Liu et al., 2021). Increasing consumption of blueberries is associated with appreciation of their organoleptic properties together with their multiple health benefits. Blueberries are fruits that are highly appreciated for their nutritional value and high concentration of bioactive substances such as vitamins, anthocyanins, and other phenolic compounds (Pérez-Lavalle et al., 2020). Blueberry is a very attractive crop mainly for its antioxidant and anti-inflammatory properties. Its content of phenolic, ascorbic acid, and anthocyanin compounds provides antioxidant action that helps to reduce cancer as well as degenerative and cardiovascular diseases. Blueberries are rich in polyphenols and antioxidants that have a positive effect on the human body, and these play an important role in the physiological functions of scavenging free radicals and antioxidant capacity (Liu et al., 2021). Along with a high antioxidant activity, this functional fruit is also well-recognized due to its hypoglycemic and insulin-sensitizing effects (Nunes et al., 2021).

Blueberry, belonging to the genus *Vaccinium*, is rich in phytochemicals such as flavonoids and polyphenols, including procyanidins, quercetin, phenolic acids, and anthocyanins. Owing to its composition, it is considered one of the main functional foods in existence having several health benefits and immunomodulatory, antioxidant, anti-inflammatory, and anti-tumor properties. Blueberries are consumed as healthy fruits that provide a variety of benefits to the nervous system. Anthocyanins are the most mentioned compounds among the components in blueberries, as they play a major role in providing the health benefits of this fruit (Tran et al., 2021). Blueberries have long since been recognized as a good source of phenolic compounds. Anthocyanins are the most prevalent family of flavonoids in blueberries (Silva et al., 2020; Wood et al., 2019). The results exhibited sonication effectively improved blueberry juice quality and enhanced its antioxidant activity (Zhou & Hou, 2017). The centrifugal block freeze concentration (CBFC) method is an interesting and novel technique to preserve important quality properties from fresh fruit juices (Casas-Forero et al., 2020). Prediction of total phenolics, anthocyanins and antioxidant capacity of blackberry (*Rubus* sp.), blueberry (*Vaccinium* sp.) and jaboticaba (*Plinia cauliflora* (Mart.) Kausel) skin using colorimetric parameters, is very promising for cost and time savings (Rigolon et al., 2020).

Bibliometric indicators have been frequently employed to analyze scientific and technological production in different

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fields of knowledge. Bibliometrics technique has been adopted in some research, such as essential oil-bearing plants exposed to the water stress (Kulak et al., 2019), grafting in horticultural plants (Belmonte-Ureña et al., 2020), scientific research about fungus Phakopsora pachyrhizi Sydow & Sydow affecting soybean [*Glycine max* (L.) Merrill] (Meira et al., 2020), highly cited articles in science citation index expanded – subject category of horticulture (Kolle et al., 2017), research, innovation and development on Corylus avellana (Raparelli & Lolletti, 2020), the berries on the top (Yeung et al., 2019), bibliometric analysis of INRA publications on fruits and vegetables produced between 2002 and 2006 (Tatry et al., 2011), tree fruit growing in Germany (Dalla Via & Baric, 2012), trends in Mango research (Kolle et al., 2018), wine research and its relationship with wine production (Jamali et al., 2020). Sun & Yuan have analyzed rice with fertilizer based on Citespace (Sun & Yuan, 2019), Library and Information Science (Sun & Yuan, 2020), Agronomy category (Sun & Yuan, 2021), scientific research on maize or corn (Yuan & Sun, 2020), muskmelon (Yuan et al., 2021a) and cucumber (Yuan et al., 2021b), strawberry research publications from Horticulture category (Yuan & Sun, 2021a) and Plant Sciences category (Yuan & Sun, 2021 b), potato research publications from Agronomy category based on Web of Science (Yuan & Sun, 2021c), et al.

The aim of the study is to assess publications of article and review on blueberry (*Vaccinium corymbosum* L.) research publications based on Web of Science by bibliometric science mapping and visualization tools. We will assess the scatter of publications in citation databases, classification of topics and progress over the years. Country input and author collaboration (co-authorship) will be addressed. Special attention will be dedicated to research topics and research fronts.

2 Data and methodology

2.1 Web of Science

Clarivate Analytics's Web of Science (WoS) is the world's leading scientific citation search and analytical information platform, and the one of the world's largest and most comprehensive academic information resources covering more than 12,000 core academic journals. The publication counts from the WoS core collection were derived from the following databases: The Science Citation Index—Expanded (SCIE)-- 1900-present, Social Science Citation Index (SSCI) --1900-present, Conference Proceeding Citation Index-Science (CPCI-S) --2015-present, Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH) --2015-present, Current Chemical Reactions (CCR-EXPANDED) --1985-present, Index Chemicus (IC) --1993-present.

2.2 Data collection and analysis

This study surveyed papers in WoS core collection (1900-present) (retrieval data last updated: 2021-9-9). We used the keywords in the title, with the query

Title: ("Blueberry" or "Blueberries" or "*Vaccinium corymbosum* L")

Then, the results were refined by Document Types (Article or Review)

At last, there were 3,872 papers from WoS Core Collection. Full record and cited references of the included papers were extracted at other reference software file format and imported into VOSviewer (version 1.6.17, 2021, Leiden University, Leiden, The Netherlands) for further citation analysis. The impact factors (IF 2020 and IF 5 year) were taken from the Journal Citation Report (JCR 2020) published in 2021, which had the latest data available.

2.3 VOSviewer

Visualizations (network and overlay) using program VOSviewer were conducted on WoS data in order to determine co-occurrence and clusters of connected publications, country input and author collaboration (co-authorship) as well as clusters of interrelated research topics. In this work, VOSviewer was showed the international collaboration between the authors, organizations, countries by co-authorship analysis and the research trends through all keywords by co-occurrence analysis (van Eck & Waltman, 2010). In this paper, default parameters values of the VOSviewer are usually used in the analysis. Items are represented by a label and a circle. The size of circles reflects the weight of an item. Some items are not displayed in avoidance of overlapping. The colors in network visualization (text maps) represent clusters of similar items as calculated by the program. Distance between the items indicates the strength of relationships. For a given item, the Links and Total link strength attributes indicate, respectively, the number of links of an item with other items and the total strength of the links of an item with other items (van Eck & Waltman, 2021).

3 Results and discussion

3.1 Document type and language of publication

Based on Clarivate Analytics's WoS Index, the 3,872 papers were SCIE (3,865), CPCI-S (60), SSCI (45), CPCI-SSH (5), IC (2), Book Citation Index–Science (1).

The paper document types and languages were displayed in the Table 1. Among the document type, there were articles (3,825, 98.786%) and reviews (47, 1.214%), also included proceedings papers (58, 1.498%), Early Access (19, 0.491%), Book Chapter (1, 0.026%). The first paper titled of "A note on Rhagoletis pomonella in blueberries" written by Woods (1914) was published in *Journal of Economic Entomology*.

All of the papers were almost published in English (3,769, 97.34%), and then others were Portuguese (35, 0.904%), German (18, 0.465%), French (14, 0.362%), Spanish (11, 0.284%), Japanese (9, 0.232%), Chinese (5, 0.129%), Korean (5, 0.129%), Italian (2, 0.052%), Polish (2, 0.052%), Lithuanian (1, 0.026%), Russian (1, 0.026%) and Turkish (1, 0.026%). The English was dominating language from the WoS, and scholars tend to publish their articles in English as they want them to be widely accepted. Most of the published documents were in the form of original

Table 1. Document type and Language of publication on blueberry research based on WoS.

Rank	Document type	Records	% of 3,872	Language	Records	% of 3,872
1	Article	3,825	98.786	English	3,769	97.34
2	Proceedings Paper	58	1.498	Portuguese	35	0.904
3	Review	47	1.214	German	18	0.465
4	Early Access	19	0.491	French	14	0.362
5	Book Chapter	1	0.026	Spanish	11	0.284
6				Japanese	9	0.232
7				Chinese	5	0.129
8				Korean	5	0.129
9				Italian	2	0.052
10				Polish	2	0.052
11				Lithuanian	1	0.026
12				Russian	1	0.026
13				Turkish	1	0.026

research articles and English was the most common language used (Khan et al., 2020).

3.2 Publication output

With the aim of knowing the research trend in blueberry research papers based on WoS, a total number of 3,872 article and review publications trend was obtained from the online version of WoS database from 1914 to 2021 and displayed in the Figure 1. The highest number value of papers (298) were published in 2020. In general, the quantity of blueberry research literature presented a fast growth tendency after 2000 year. The ratio of the publications after 1960, 1970, 1980, 1990, 2000 and 2010 till July 3, 2021 were 97.75%, 95.74%, 90.86% 81.97%, 72.75% and 57.98%, respectively. The *h*-index was initially proposed as a measure of a researcher's scientific output based on counting the number of publications (N) by that researcher cited N or more times (Hirsch, 2005). For the total 3,872 papers, sum of the times cited is 73,319, the *h*-index is 102, and the average citation per item is 18.94 times.

3.3 Web of Science categories and research areas

For blueberry research publications based on WoS, there were total 136 WoS subject categories in the science edition (total 254 categories) and 96 research areas. Table 2 showed the top 20 WoS categories and the research areas in the subject of blueberry research publications based on WoS. The top 5 WoS categories included Horticulture (996, 25.72%), Food Science Technology (975, 25.18%), Plant Sciences (721, 18.62%), Agronomy (406, 10.49%) and Agriculture Multidisciplinary (315, 8.14%). The top 5 research areas included Agriculture (1,647, 42.54%), Food Science Technology (975, 25.18%), Plant Sciences (721, 18.62%), Chemistry (421, 10.87%) and Nutrition Dietetics (290, 7.49). The journals or papers may be classified into two or more categories in the WoS, shows the multidisciplinary character of this research field (Elango & Ho, 2017, 2018). In WoS, publications are also mapped to WoS categories which are more detailed than areas (Stopar et al., 2021).

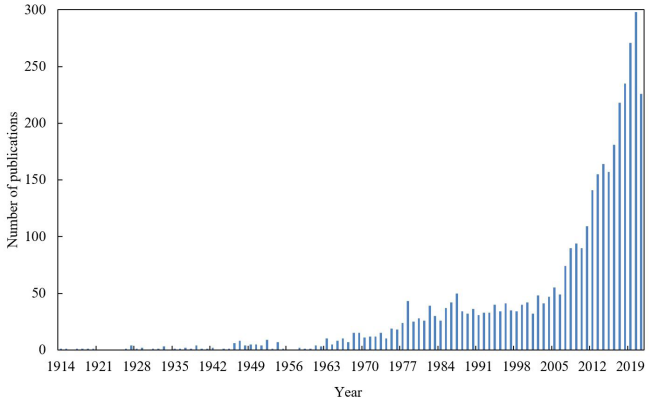

Figure 1. Number of published papers of blueberry research based on Web of Science from 1914 to 2021.

3.4 Core journals

Based on JCR 2020 data (published in 2021), there were 770 Journals and three book series for blueberry research publication based on WoS. The top 20 core journals were displayed in the Table 3 with total articles each more than 28 papers, Journal impact factor as IF 2020 and IF 5 year, and Quartile in Category (QC).

The top 5, top 10, top 15 and top 20 Journals published about 22.08%, 31.35%, 37.40% and 41.48% of the total papers, respectively. The top five Journals were *HortScience* (278, 7.18%), *Journal of the American Society for Horticultural Science (Proceedings of the American Society for Horticultural Science)* (272, 7.024%), *Journal of Agricultural and Food Chemistry* (116, 2.996%), *Journal of Economic Entomology* (97, 2.505%), *Food Chemistry* (92, 2.376%), that these journals each published more than 92 papers. Based on Table 3 of the top 20 journals, there were nine journals in Quartile 1, five journals in Quartile 2, five journals in Quartile 3, and one journal was old journal with no IF. White-Gibson et al. (2019) had demonstrated the importance of publishing in the English language and in a journal with a high impact factor. Citation analysis is not a measurement of scientific quality, but it is reflective of the importance (White-Gibson et al., 2019).

Table 2. Top 20 WoS categories and research areas for blueberry research based on WoS.

Rank	WoS categories	TP	Ratio	Research areas	TP	Ratio
1	Horticulture	996	25.723	Agriculture	1,647	42.536
2	Food Science Technology	975	25.181	Food Science Technology	975	25.181
3	Plant Sciences	721	18.621	Plant Sciences	721	18.621
4	Agronomy	406	10.486	Chemistry	421	10.873
5	Agriculture Multidisciplinary	315	8.135	Nutrition Dietetics	290	7.49
6	Chemistry Applied	314	8.11	Entomology	287	7.412
7	Nutrition Dietetics	290	7.49	Biochemistry Molecular Biology	155	4.003
8	Entomology	287	7.412	Environmental Sciences Ecology	144	3.719
9	Biochemistry Molecular Biology	145	3.745	Biotechnology Applied Microbiology	89	2.299
10	Environmental Sciences	95	2.454	Science Technology other Topics	83	2.144
11	Biotechnology Applied Microbiology	89	2.299	Pharmacology Pharmacy	77	1.989
12	Multidisciplinary Sciences	72	1.86	Engineering	75	1.937
13	Agricultural Engineering	69	1.782	Genetics Heredity	58	1.498
14	Soil Science	64	1.653	Microbiology	48	1.24
15	Engineering Chemical	60	1.55	Neurosciences Neurology	37	0.956
16	Genetics Heredity	58	1.498	Toxicology	35	0.904
17	Chemistry Multidisciplinary	56	1.446	Cell Biology	27	0.697
18	Ecology	52	1.343	Forestry	24	0.62
19	Chemistry Medicinal	48	1.24	Virology	24	0.62
20	Microbiology	48	1.24	Oncology	22	0.568

TP = total publication; Ratio = Ratio of 3,872 (%).

Table 3. Top 20 Journals on blueberry research based on WoS.

Rank	Journal	TP	Ratio	IF 2020	IF 5 year	QC
1	*HortScience*	278	7.18	1.455	1.617	Q2
2	*Journal of the American Society for Horticultural Science (Proceedings of the American Society for Horticultural Science)*	272	7.024	1.144	1.617	Q3
3	*Journal of Agricultural and Food Chemistry*	116	2.996	5.279	5.269	Q1
4	*Journal of Economic Entomology*	97	2.505	2.381	2.568	Q2
5	*Food Chemistry*	92	2.376	7.514	7.516	Q1
6	*Canadian Journal of Plant Science*	83	2.144	1.018	1.242	Q3
7	*Scientia Horticulturae*	76	1.963	3.463	3.672	Q1
8	*Journal of Food Science*	74	1.911	3.167	3.376	Q2
9	*Phytopathology*	71	1.834	4.025	4.394	Q1
10	*Plant Disease*	55	1.42	4.438	4.7	Q1
11	*LWT Food Science and Technology*	53	1.369	4.952	5.383	Q1
12	*Postharvest Biology and Technology*	50	1.291	5.537	5.821	Q1
13	*Fruit Varieties Journal*	45	1.162			
14	*Environmental Entomology*	43	1.111	2.377	2.298	Q2
15	*Journal of the Science of Food and Agriculture*	43	1.111	3.638	3.802	Q1
16	*Horttechnology*	36	0.93	1.087	1.059	Q3
17	*PloS One*	34	0.878	3.24	3.788	Q2
18	*Canadian Entomologist*	31	0.801	0.973	1.358	Q3
19	*Food Function*	29	0.749	5.396	5.534	Q1
20	*Revista Brasileira De Fruticultura*	28	0.723	0.912	0.968	Q3

TP = total publication, Ratio of 3,872 (%); IF 2020 and IF 5years; QC = Quartile in Category; Data were from the 2020 edition of Journal Citation Reports.

According to the publication data in the citation of 770 journals, there were 153 journals meet the thresholds of 5 publications. The network of citation in the field of blueberry research based on WoS was shown 8 clusters with different colors in Figure 2, the size of circles reflects a total number of journal publication records. Journals in the same cluster usually suggested that they

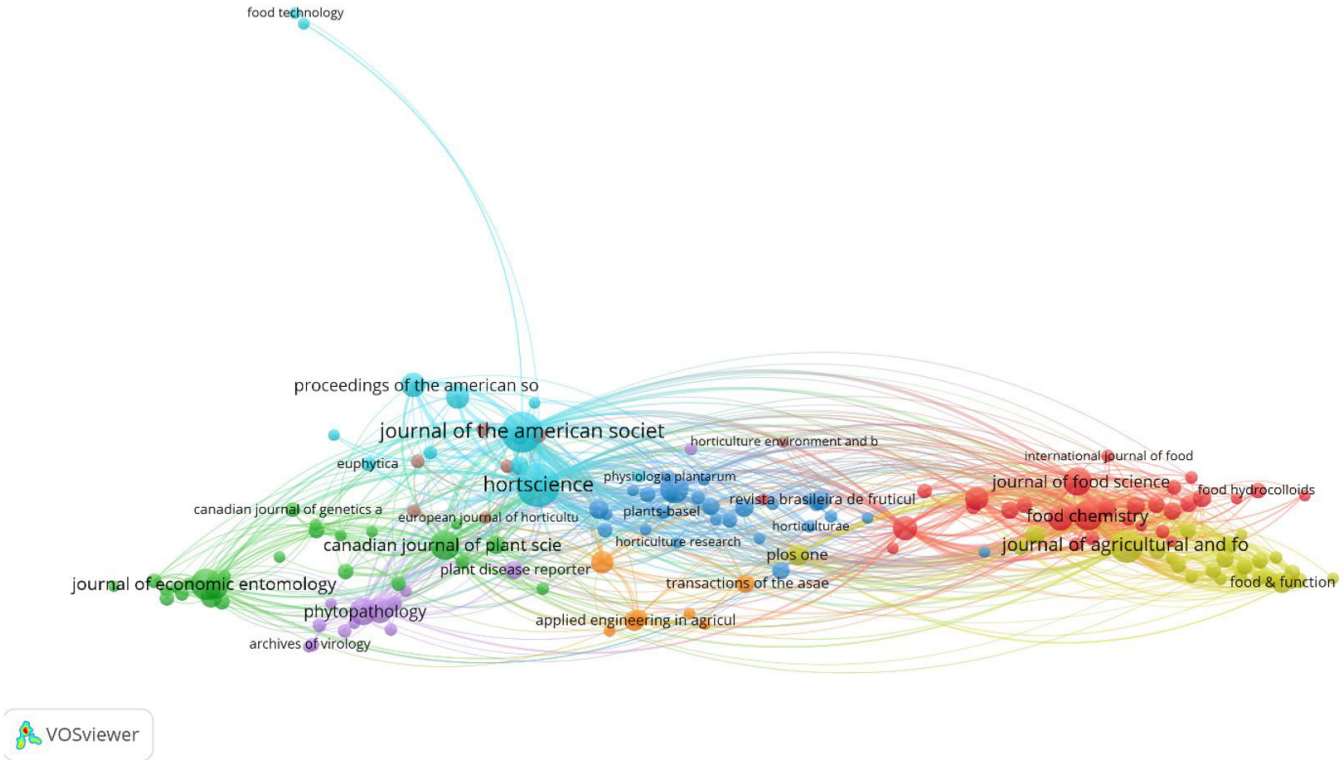

Figure 2. Network visualization maps of citation journals in blueberry research based on Web of Science with 151 nodes and 8 clusters.

published the similar content papers and had close relations with each other.

3.5 Authors co-authorship analysis

In general, internationally collaborative articles had the highest visibility and scientific impact followed by inter-institutional collaborative articles, single-country articles and single-author articles, respectively (Wambu & Ho, 2016). According to the publication data, it was revealed that a total of 10,102 authors published 3,872 publications, there were 380 authors meet the thresholds of 5 publications, but only 113 authors were connected to each other. The network of authorship in the field of Network visualization maps of authors of blueberry research publications based on WoS was shown in Figure 3, the size of circles reflected a total number of records. Authors in the same cluster usually suggested that they studied in a similar field and had close cooperation with each other.

Table 4 show top 22 authors published more than 27 papers, and also lay the citations, average citations, organization-enhanced and countries. The top five authors were Hancock, James F. (Hancock, Jf; Hancock, J), Rowland, Lisa J. (Rowland, LJ), Ehlenfeldt, Mark K. (Ehlenfeldt, MK), Lyrene, Paul M.(Lyrene, PM), and Strik, Bernadine C., each published more than 39 papers. The top five authors with the higher citations per paper were Shukitt-Hale, Barbara (Shukitt-Hale, B), Rowland, Lisa J. (Rowland, LJ), Hancock, James F. (Hancock, JF; Hancock, J), Isaacs, Rufus (Isaacs, R), and Ehlenfeldt, Mark K.(Ehlenfeldt, MK), average citations per paper are more than 24.00 times.

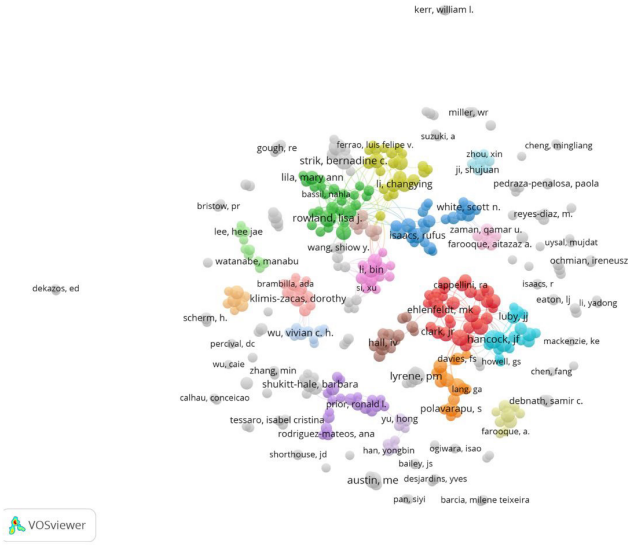

Figure 3. Network visualization maps of authors of blueberry research based on Web of Science.

The top 22 authors were mainly from USA and Canada. There were 18 authors from USA, three authors were from Canada, one author was from Chile.

3.6 Countries/regions co-authorship analysis

There are 83 countries or regions contributing the 3,872 papers in this study. Table 5 lists the top 20 countries or regions that

Table 4. The top 22 most prolific authors published papers in the field of blueberry research based on Web of Science.

Rank	Author	Papers	Citations	Avg. citations	Organization-Enhanced	Country
1	Hancock, James F. (Hancock, JF; Hancock, J)	58	1,442	24.86	Michigan State University	USA
2	Rowland, Lisa J. (Rowland, LJ)	55	1,475	26.82	ARS	USA
3	Ehlenfeldt, Mark K.(Ehlenfeldt, MK)	48	1,152	24.00	USDA ARS	USA
4	Lyrene, Paul M.(Lyrene, PM)	48	560	11.67	University of Florida	USA
5	Strik, Bernadine C.	39	588	15.08	Oregon State University	USA
6	Zaman, Qamar U. (Zaman, Q.U.; Zaman, Q.)	38	306	8.05	Dalhousie University	Canada
7	Spiers, JM	37	409	11.05	ARS USDA	USA
8	Bryla, David R.	33	466	14.12	ARS USDA	USA
9	Scherm, Harald (Scherm, H.; Scherm, H)	33	413	12.52	University of Georgia	USA
10	Drummond, Francis A. (Drummond, Francis)	32	334	10.44	University of Maine	USA
11	Williamson, Jeffrey G. (Williamson, Jeffrey; Williamson, JG)	32	312	9.75	University of Florida	USA
12	Isaacs, Rufus (Isaacs, R)	31	753	24.29	Michigan State University	USA
13	Percival, David C. (Percival, David; Percival, D. C.; Percival, DC)	31	318	10.26	Dalhousie University	Canada
14	Ramsdell, DC	31	325	10.48	Michigan State University	USA
15	Draper, AD	29	318	10.97	ARS USDA	USA
16	Farooque, Aitazaz A. (Farooque, A. A.; Farooque, A.)	29	228	7.86	University of Prince Edward Island	Canada
17	Schumann, Arnold W. (Schumann, A.W.)	29	325	11.21	University of Florida	USA
18	Austin, ME	28	180	6.43	University of Georgia	USA
19	Vorsa, Nicholi (Vorsa, N)	28	477	17.04	⁋Rutgers State University	USA
20	Darnell, Rebecca L. (Darnell, RL)	27	367	13.59	University of Florida	USA
21	Reyes-Diaz, Marjorie (Reyes-Diaz, M.)	27	409	15.15	Universidad de La Frontera	Chile
22	Shukitt-Hale, Barbara (Shukitt-Hale, B)	27	3,178	117.70	Tufts University	USA

the publications were above 22 papers ranked by the number of total publications, and also list the cluster, total link strength, citations and average citations. USA, Peoples R China, Canada, Chile and Brazil are the five most papers countries, each with

We developed the international country co-authorship network map using VOSviewer software. There were 48 countries or regions meeting the requirement as 5 threshold and connected to each other in Figure 4, the VOSviewer software divided these 48 countries into 7 clusters with different colors, the size of circles reflected a total number of records and the distance between the countries indicated the strength of relationships. The different colors group, the different clusters formed by sets of countries.

As we can see from Figure 4, the first cluster consisted of 10 countries and regions (red color), Italy, Poland, England, Finland, Czech Republic, Lithuania, Slovenia, Netherlands, Switzerland, Austria, et al. The second cluster consisted of 8 countries or regions (green color), Chile, Spain, Argentina, South Africa, Colombia, Malaysia, Ecuador and Uruguay. The third cluster consisted of 8 countries and regions (blue color), South Korea, Croatia, Serbia, Sweden, India, Norway, Taiwan and Estonia. The fourth cluster consisted of 7 countries and regions (yellow color), Turkey, Germany, France, Romania, Greece, Israel and Belgium. The fifth cluster consisted of 6 countries (violet), USA, Peoples R China, Canada, Egypt, Pakistan and Saudi Arabia. The sixth

Table 5. Top 20 countries/regions publishing papers of blueberry research based on WoS.

Rank	Countries/Regions	Records	Cluster	Total link strength	Citations	Avg. citations
1	USA	1,555	5	378	37,645	24.21
2	Peoples R China	500	5	158	7,056	14.11
3	Canada	436	5	137	8,384	19.23
4	Chile	151	2	78	2,197	14.55
5	Brazil	128	7	45	1,923	15.02
6	Italy	105	1	62	2,848	27.12
7	Japan	83	7	15	971	11.70
8	South Korea	82	3	27	941	11.48
9	Spain	74	2	71	1,803	24.36
10	Poland	72	1	7	856	11.89
11	Argentina	55	2	19	853	15.51
12	England	53	1	46	1,549	29.23
13	Turkey	49	4	22	1,018	20.78
14	New Zealand	41	6	23	906	22.10
15	Australia	39	6	28	829	21.26
16	Germany	39	4	33	1,429	36.64
17	Portugal	33	7	12	761	23.06
18	Mexico	32	7	28	603	18.84
19	France	31	4	29	654	21.10
20	Romania	22	4	6	408	18.55

More than 128 papers; From the average citations, Germany, England, Italy, Spain and USA, showed the higher citations per paper more than 24.209 times.

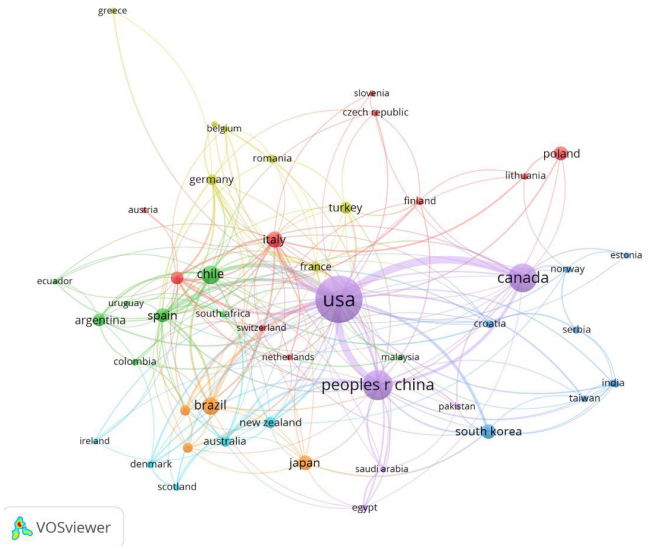

Figure 4. The country co-authorship network of blueberry research based on Web of Science with 48 nodes and 8 clusters.

cluster consisted of 5 countries (shallow blue), New Zealand, Australia, Denmark, Scotland and Ireland. The seventh cluster consisted of 4 countries (orange), Brazil, Japan, Portugal and Mexico. Therefore, geographical location is an important factor that determines international cooperation. More cooperation could bring more advanced achievements in scientific research. Nowadays, increasing international exchanges have promoted academic communications (Tang et al., 2018).

3.7 Organizations co-authorship analysis

According to the publication data, it was revealed that a total of 2,033 organizations published 3,872 publications. Organization co-authorship analysis reflected the degree of communication between institutions as well as the influential institutions in this field (Reyes-Gonzalez et al., 2016). Table 6 listed the top 20 organizations and institutions that the publications were above 28 papers ranked by the number of total publications, and also showed the total link strength, citations, average citations and country. These organizations were mainly focused in USA with 12 organizations; Canada with 4 organizations; China with 2 organizations; Italy with 1 organizations; Chile with 1 organization. The six most paper contributed organizations were USDA ARS (USDA, ARS), University of Florida, Michigan State University, University of Georgia, Agriculture and Agri-Food Canada, and University of Maine, each published more than 128 papers. The top five organizations of Tufts University, University of Milan, University of Arkansas, Agriculture and Agri-Food Canada, and USDA ARS showed the higher average citations more than 27.07 times.

Of the all 2,033 organizations, there were 202 organizations meet the minimum thresholds of 5, but 178 organizations connected to each other in Figure 5, the VOSviewer software divided these 178 institutes into 18 clusters with different colors. Geographical localization is an important factor for partnership and joint venture. Therefore, there were heavy presence of intra-institutional relationships within the scientific network on publications.

Table 6. Top 20 organizations publishing papers in the field of blueberry research based on WoS.

Rank	Organizations	Records	TLS	Citations	Avg. C	Country
1	USDA ARS (USDA, ARS)	360	347	9,744	27.07	USA
2	University of Florida	207	144	2,253	18.08	USA
3	Michigan State University	163	115	3,291	20.19	USA
4	University of Georgia	162	83	3,386	20.90	USA
5	Agriculture and Agri-Food Canada	128	118	3,703	28.93	Canada
6	University of Maine	128	76	2,696	21.06	USA
7	Rutgers State University	121	106	2,639	21.81	USA
8	Dalhousie University	93	85	739	7.95	Canada
9	North (N) Carolina State University	79	72	1,535	19.43	USA
10	Oregon State University	77	84	2,000	25.97	USA
11	Nova Scotia Agricultural College	55	36	703	12.78	Canada
12	Universidad de La Frontera	55	72	630	11.45	Chile
13	University of Arkansas	48	39	1,787	37.23	USA
14	Shenyang Agricultural University	46	14	731	15.89	China
15	Washington State University	43	50	777	18.07	USA
16	Tufts University	40	22	4,236	105.90	USA
17	University of Laval	32	19	682	21.31	Canada
18	University of Milan	30	24	1,520	50.67	Italy
19	Chinese Academy of Sciences	28	26	422	15.07	China
20	Cornell University	28	37	476	17.00	USA

TLS = Total Link Strength; Avg. C = Average Citations

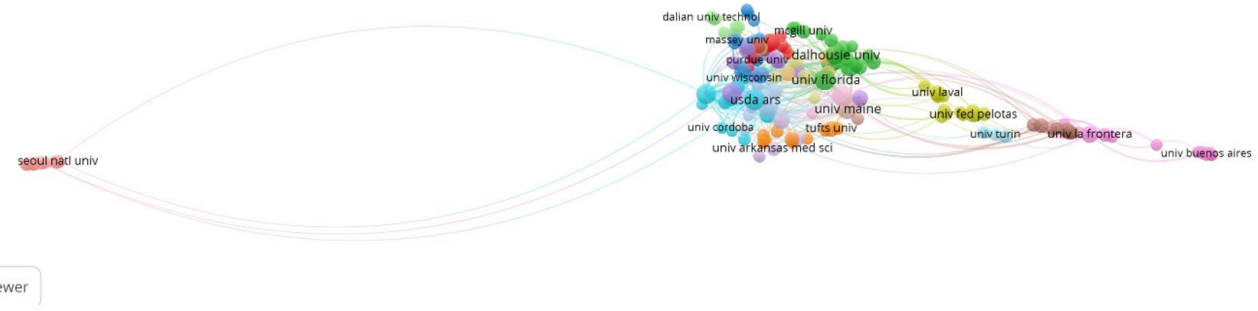

Figure 5. The organizations co-authorship network of blueberry research based on WoS.

3.8 All Keywords co-occurrence analysis

Using the VOSviewer, the mappings can be made for the author keywords, keyword plus and all keywords. For the author keywords, there were 6,697 keywords, and 402 keywords met the threshold level of more than five times. The top twenty co-occurrence keywords were blueberry, *vaccinium corymbosum*, anthocyanins, blueberries, vaccinium, *vaccinium angustifolium*, anthocyanin, antioxidant activity, *vaccinium ashei*, polyphenols, antioxidant, highbush blueberry, oxidative stress, phenolics, wild blueberry, antioxidants, fruit quality, antioxidant capacity, pollination, lowbush blueberry, et al., each keywords occurred more than 42 times. For the keywords plus, there were 5,921 keywords, and 787 keywords met the threshold level of more than five times. The top twenty co-occurrence keywords were anthocyanins, fruit, growth, antioxidant capacity, quality, identification, phenolic-compounds, cultivars, yield, oxidative stress, antioxidant activity, capacity, fruits, polyphenols, highbush blueberry, expression, storage, in-vitro, phenolics, temperature, et al., each keywords occurred more than 94 times.

Figure 6 shows the network map that links the all keywords to the entire sample of the articles analyzed. Of the all 11,366 keywords, there were only 954 keywords meet the

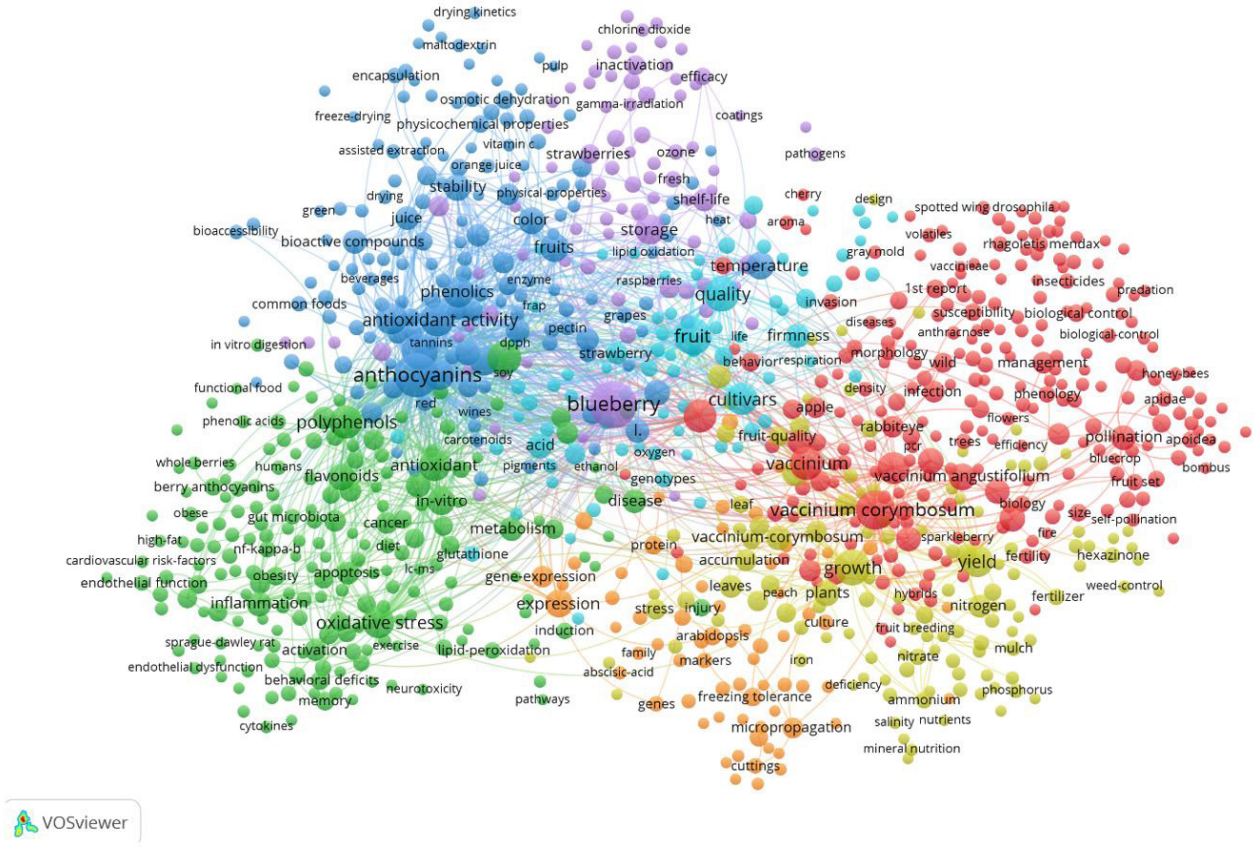

Figure 6. VOSviewer co-occurrence Network visualization mapping of most frequent all keywords (minimum of 6 occurrences) in blueberry research based on WoS.

threshold more than 6 co-occurrence, which were separated into 7 main clusters viewpoints on blueberry research based on WoS (Figure 6). The top twenty co-occurrence keywords were blueberry, anthocyanins, *vaccinium corymbosum*, fruit, antioxidant capacity, growth, quality, blueberries, antioxidant activity, vaccinium, identification, polyphenols, oxidative stress, highbush blueberry, cultivars, yield, phenolic-compounds, antioxidant, phenolics, storage, et al., each more than 138 times.

Then, the same data were arranged as overlay map (Figure 7). According to the manual for VOSviewer version 1.6.17 (van Eck & Waltman, 2021), blue colors indicate earlier research topics, whereas, yellow and green colors indicate more recent topics of interest. If a topic is presented in blue, it does not mean that there is now no longer any research to this end. It usually means that, on average, this topic was intensely investigated earlier and that now more attention has shifted towards other topics. Yellow and green circles present those research fronts.

The top 20 keywords were list and ranked in each cluster (Figure 6).

The first cluster (Red) is focused on blueberries (*vaccinium corymbosum*) identification, including keyword terms as *vaccinium corymbosum*, *vaccinium*, identification, highbush blueberry, *vaccinium angustifolium*, lowbush blueberry, rabbiteye blueberry, pollination, *vaccinium ashei*, ericaceae, resistance, *vaccinium-angustifolium*, diversity, management, infection, rabbiteye, apple, hymenoptera, plant, *vaccinium* spp., et al., each keywords occurred more than 38 times.

The second cluster (Green) represents the oxidative stress of blueberries polyphenols and health, keyword terms ranked as blueberries, polyphenols, oxidative stress, antioxidant, in-vitro, flavonoids, inflammation, antioxidants, metabolism, disease, apoptosis, extract, cancer, bioavailability, consumption, activation, cranberry, insulin-resistance, health, blood-pressure, et al., each keywords occurred more than 39 times.

The third cluster (blue) is focused on antioxidant capacity and activity of anthocyanins in berries, including keyword terms as anthocyanins, antioxidant capacity, antioxidant activity, phenolic-compounds, phenolics, capacity, anthocyanin, fruits, temperature, stability, color, highbush, berries, extracts, bioactive compounds, juice, extraction, *vaccinium-corymbosum* L., kinetics, degradation, et al., each keywords occurred more than 46 times.

The fourth cluster (yellow) represents plants growth and yield response to conditions, keyword terms ranked as growth, yield, plants, *vaccinium-corymbosum*, wild blueberry, nitrogen, impact, leaves, accumulation, fruit quality, soil, stress, ph, tolerance, fruit-

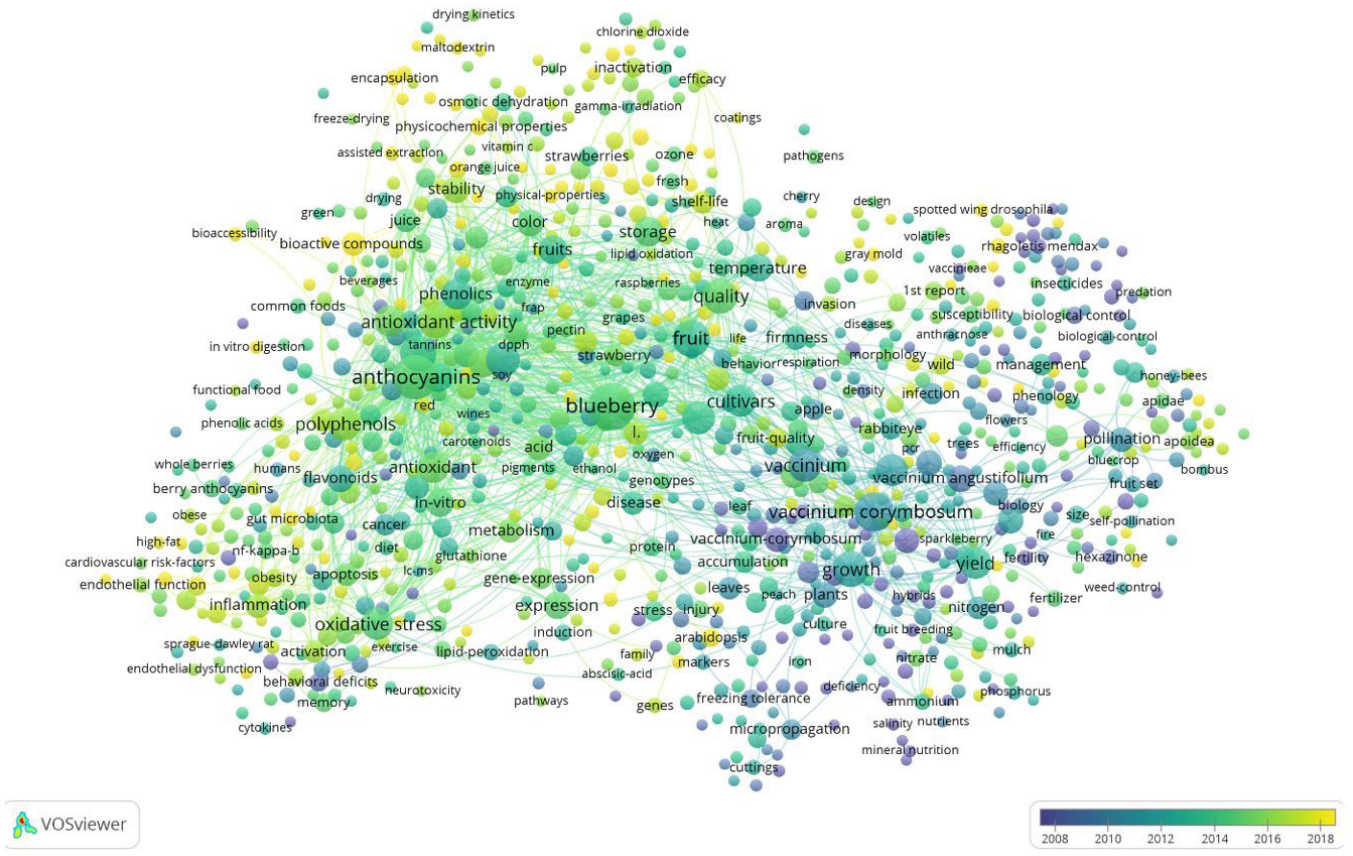

Figure 7. VOSviewer co-occurrence overlay visualization mapping of most frequent all keywords (minimum of 6 occurrences) in blueberry research based on WoS.

quality, *vaccinium-ashei*, responses, photosynthesis, nutrition, cultivar, et al., each keywords occurred more than 31 times.

The fifth cluster (violet) is focused on blueberry storage and postharvest quality varies , including keyword terms as blueberry, storage, shelf-life, vegetables, inactivation, strawberries, water, United-States, proanthocyanidins, efficacy, decay, escherichia-coli, salmonella, chitosan, chemical-composition, edible coatings, bacteria, fresh, listeria-monocytogenes, et al., each keywords occurred more than 20 times.

The sixth cluster (shallow blue) is focused on fruit quality of cultivars, keyword terms ranked as fruit, quality, cultivars, acid, firmness, strawberry, anthocyanin content, highbush blueberries, texture, postharvest, genotypes, phenolic content, prediction, maturity, apples, enzymes, ethylene, glutathione, oxygen, radical absorbing capacity, et al., each keywords occurred more than 15 times.

The seventh cluster (orange) is focused on biosynthesis and gene-expression, keyword terms as expression, gene-expression, micropropagation, Arabidopsis, freezing tolerance, protein, propagation, proteins, biosynthesis, gene, light, genes, low-temperature, cold-acclimation, culture, cuttings, markers, *arabidopsis-thaliana*, cold hardiness, regeneration, et al., each keywords occurred more than 15 times.

3.9. Top papers based on Essential Science Indicators (ESI)

Top papers are the sum of hot papers and highly cited papers, based on Clarivate Analytics' Essential Science Indicators (ESI). Highly cited paper is a paper that belongs to the top 1% of papers in a research field published in a specified year. The 1% is determined by the highly cited threshold calculated for the research field in the specified year. Hot paper is a paper published in the past two years that received a number of citations in the most recent two-month period that places it in the top 0.1% of papers in the same field. Here, the Essential Science Indicators database covers over a 10-year and 6-month period: January 1, 2011 – June 30 , 2021(Clarivate, 2021. Essential Science Indicators Help).

Based on ESI database, these top papers are 25 highly cited papers, with one hot paper. From 2012 to 2021, there are top papers as 1, 2, 3, 3, 4, 2, 1, 3, 3, 3 papers, respectively. These 25 top papers are published in *Advances in Nutrition* (1), *American Journal of Clinical Nutrition* (1), *Environmental Entomology* (2), *Food Chemistry* (7), *Food Hydrocolloids* (1), *Food Microbiology* (1), *Gigascience* (1), *Innovative Food Science & Emerging Technologies* (1), *Journal of Applied Entomology* (1), *Journal of Food Engineering* (1), *Journal of Nutrition* (1), *Journal of Nutritional Biochemistry*(1), *Journal of the Academy*

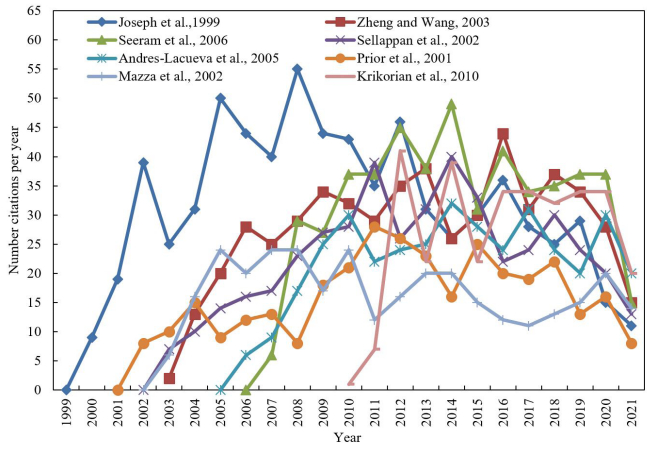

Figure 8. Comparison of the citations per year of the most eight papers from their initial publications to September 9, 2021.

of Nutrition and Dietetics (1), *LWT-Food Science and Technology* (1), *New Phytologist* (1), *Plant Physiology* (1), *Postharvest Biology and Technology* (1), and *Scientific Reports* (1), et al. Among that, the paper published in *LWT-Food Science and Technology* was both the highly cited paper and hot paper. For the 25 top papers, the *h*-index is 21, the sum of total citations are 2558, and the average citation per item is 102.32.

3.10 The most frequently cited articles

Although a great many articles have been published, a relatively small number of individuals account for a large proportion of the citations within the period. Here, the total citations for the eight most frequently cited articles were more than 320 times. The 8 most cited papers were published in *Journal of Agricultural and Food Chemistry* (Zheng & Wang, 2003; Seeram et al., 2006; Sellappan et al., 2002; Prior et al., 2001; Mazza et al., 2002; Krikorian et al., 2010), *Journal of Neuroscience* (Joseph et al., 1999; Andres-Lacueva et al., 2005). The total citations of the most cited 8 papers were 711, 530, 498, 444, 367, 330, 323 and 320, and the average citations per year are 30.91, 27.89, 31.13, 22.2, 21.59, 15.71, 16.15 and 26.67, respectively. From Figure 8, it can be found that the citation per year of the papers increased till to 2021, but the increase rate is different. The citations per year is still increased for the paper (green line) published in *Journal of Agricultural and Food Chemistry* and written by Seeram et al. (2006), and the average citations per year is the highest value as 31.13 (green line) among the 8 papers. The number of citations to a paper is considered a good quantitative measure of a paper's impact.

4 Conclusions

This study analyzed 3,872 article and review type papers of blueberry research publications based on the Web of Science, papers mainly written in English (97.34%), were from 10,102 authors, 83 countries/territories, 2,033 organizations and published in 770 Journals and three book series. The top five Journals are *HortScience*, *Journal of the American Society for Horticultural Science (Proceedings of the American Society for Horticultural Science)*, *Journal of Agricultural and Food Chemistry*, *Journal of Economic Entomology* and *Food Chemistry*. The top five countries and regions were USA, Peoples R China, Canada, Chile and Brazil. The six most paper contributed organizations were USDA ARS (USDA, ARS), University of Florida, Michigan State University, University of Georgia, Agriculture and Agri-Food Canada, and University of Maine. The top five authors were Hancock, James F. (Hancock, Jf; Hancock, J), Rowland, Lisa J. (Rowland, LJ), Ehlenfeldt, Mark K. (Ehlenfeldt, MK), Lyrene, Paul M. (Lyrene, PM), and Strik, Bernadine C. All keywords of the blueberry research based on Web of Science were separated seven clusters for different research topics. This work is useful for student identifying graduate schools and researchers selecting journals.

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