Research partnerships in relation to topics in animal breeding and genetics[1]

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ABSTRACT: A total of 1,628 papers presented at the sixth and seventh World Congresses on Genetics Applied to Livestock Production were categorized into 20 topics according to research subjects. The aim was to determine, in relation to various topics in animal breeding and genetics, the forms of partnerships and the degree of attention given in different continents. North–North partnerships (defined as cooperation between and within developed countries) had a 68.80% representation of research papers presented, whereas North–South partnerships (cooperation between developed and developing countries) had the least representation with only 8.23% of papers. Asia contributed the most research papers in biochemical genetics, whereas Australia lead in research papers on breeding for fiber and fur. Europe contributed the most to the remaining topics, and Africa usually, but not always, contributed the least to most research topics. This study provided a useful indication of the current state of literature in animal breeding and genetics and will be useful to animal breeding and genetics researchers worldwide as they chart the way forward for research and development in the field of genetics applied to livestock production in different continents.

Key words: animal breeding, developing country, genetics, livestock production, research partnership

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INTRODUCTION

The world's population is expected to grow from 6 billion people in 2000 to 7.5 billion people in 2020, with most of this growth occurring in developing countries, where poverty is most prevalent; therefore, most of the increase in food production is needed in these countries (Tollens, 1998; IFPRI, 2001). In the fight against poverty, livestock researchers have a special responsibility because all indicators reveal that the next food revolution will be a "livestock revolution" (Delgado et al., 1999). However, the capacity of many developing countries to conduct their own livestock research and development is minimal; thus, there is the need to develop scientific capacity through partnerships with universities and research institutions of the developed countries, so that they develop their own technologies and deal with technologies offered by the developed countries (Tollens et al., 2004).

Research partnerships can result in sound research and development goals but information on levels of research partnerships in animal breeding and genetics is lacking. Research partnerships usually culminate in results that are presented at different platforms including international, regional, and national scientific conferences and refereed journals. A great number of scientific articles presented at scientific conferences are never published in refereed journals. Therefore, conference proceedings carry the majority of the research literature. The most extensive representation of animal breeding and genetics research occurs at the World Congress on Genetics Applied to Livestock Production (**WCGALP**). In this study, papers presented at the sixth and seventh WCGALP were analyzed 1) to establish the degree of attention given to the various topics in animal breeding and genetics in different continents, and 2) to determine the nature of partnerships in relation to these topics.

MATERIALS AND METHODS

The World Congress on Genetics Applied to Livestock Production was launched in 1974 in Europe. Meeting every 4 yr since 1986, the WCGALP is the main interna-

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tional meeting of scientists involved in research on genetics applied to livestock production. The conference proceedings are published every 4 yr, meaning scientists have enough time between the meetings to pursue important subjects for presentation at the conference. These proceedings capture relevant ongoing and completed research work in both developed and developing countries. The conference is an important forum for future prospects of animal breeding. The sixth WCGALP was hosted in Armidale, Australia, in 1998, and the seventh congress was hosted in Montpellier, France, in 2002. In total, 684 papers were included in the 6 proceedings volumes of the 1998 meeting, and 944 papers in the 5 volumes of the 2002 meeting.

Categorization of Papers

To categorize papers, general definitions were given to the main research topics highlighted in the conferences. The key subjects given by the WCGALP organizing committees for the different sessions were considered as the principal guideline in the categorization process. All sessions were reviewed to establish broad clusters by combining similar topics. Table 1 shows the key article categories identified from the sixth and seventh WCGALP. An additional category for papers that could not be expressly categorized in any group was the "subject support" category. Papers were assigned to up to 3 categories, according to the most relevant subjects covered. The abstracts for each paper were reviewed independently first before being finally approved for categorization in a joint meeting. The categories defined in Table 1 were coded from 1 to 20 for ease of assignment of papers to relevant categories based on the topics covered. For abstracts that generated contrary opinions, the full text of the papers was considered for review before the final decisions were made.

Data Collected for each Paper

Bibliography and Character of Paper. In addition to the category, the name of the first author, the year, the volume number, and the first page of each article were collected. The papers were then characterized as theoretical, empirical, or reviews. Empirical articles were those that presented quantitative or qualitative analyses, or theoretical simulations papers that did not involve analytical procedures, and also included papers presenting new statistical or biometrical methods, whereas reviews were those that discussed past studies on important topics.

Geographical Context. The sources of information were used to determine the geographical context of the paper. For papers that had information from a single country, the country was considered as the context. This was also the case for theoretical and analytical studies that used deterministic solutions or simulated data. The continent was considered as the context in papers with 2 or more countries in the same continent as sources of information. Table 2 shows the categorization of various countries represented in 6 continents. For papers that analyzed information from countries across continents, the world was considered as the context. Similarly, the world was considered as the context for review papers that summarized studies done all over the world.

Nature of Research Partnerships. With reference to the geographical context, the location of the institution with which the author was affiliated was considered for identification of the nature of partnership. The nature of partnerships described in this study were: North–North (**N–N**) partnerships, defined as cooperation between and within developed countries; North–South (**N–S**) partnerships, defined as cooperation between developed and developing countries; and South–South (**S–S**) partnerships, defined as cooperation between and within developing countries. Table 2 shows a categorization into developed and developing countries of the various countries represented. The categorization into developed and developing countries was based on the World Bank's country classification (World Bank, 2006).

In papers with more than 1 author, the location of the institution with which the first 2 authors and the last author were affiliated was used to deduce the nature of partnerships involved in the research. Therefore, papers with 1 author or 2 authors from the same institution were categorized as either an N–N or a S–S partnership depending on where their respective institutions were located. In general, 12.09% of papers were by single authors; the remainder was from multiple authors from institutions located in 1 country (67.83%) or different countries (20.38%).

Data Analyses

Data were analyzed using SAS (SAS Institute Inc., Cary, NC). Frequencies were tabulated and χ^2 analysis was performed using PROC FREQ. The χ^2 analyses were performed to determine the association between the various topics in animal breeding and genetics and continental representation and nature of the research partnership.

RESULTS

Authorship, Character, and Geographical Context of Papers

Table 3 shows the authorship of papers by continent. Here, the papers were assigned to continents on the basis of the institutional affiliation of the authors. The most represented continent was Europe with 1,641 presentations, whereas the least represented was Africa with only 200 representations. It is clear that Africa-based scientists gave less attention to empirical and theoretical research in animal breeding and genetics, which form the majority of the papers presented at the WCGALP.

Table 1. Key article categories identified from the sixth and seventh World Congresses on Genetics Applied to Livestock Production

Code	Category	Definition
1	Behavior and welfare	Evaluation of animal behavior in relation to animal environment, influence on temperament and measurement of behavioral traits
2	Biochemical genetics	Biological aspects and biochemical information applicable in animal genetics research
3	Breeding for fiber and fur	Genetic and economic evaluation of fiber and fur production including analysis of functional traits
4	Breeding for meat production	Analysis of meat production traits, estimation of means, variances, correlation and economics of meat production including analysis of functional traits
5	Breeding for milk production	Analysis of milk production traits, estimation of means, variances, correlation and economics of milk production including analysis of functional traits
6	Breeding for nonconventional or regional species	Characterization of nonconventional and regional species, economic and genetic aspects
7	Capacity building in animal breeding and genetics	Curriculum development, training opportunities and prospects for undergraduate and postgraduate education in animal breeding and genetics
8	Computer and information technology	Design and development of computer programs. Software packages for the genetic management of animals
9	Design of sustainable breeding programs and strategies	Development of breeding objectives, estimation of economic values of traits, assessment of genetic progress and the description of breeding structures. Mating systems for production of optimal breed mixes to maximize expressions of important animal traits
10	Detection of QTL	Analysis of methodologies for detection of QTL and the effects of major genes on distribution of quantitative traits
11	Developmental genetics	Identification and presentation of new challenges in animal breeding and genetics research
12	Disease resistance	Breeding for disease resistance, analysis of relationship between other animal traits and disease resistance
13	Estimation of genetic parameters	Crossbreeding parameters, heritability of, variance of, correlation between animal traits, including methods of estimation of crossbreeding and other genetic parameters
14	Experimental and observational quantitative genetics	Analysis of modes of inheritance of genes through experimentation and observation in laboratory and field
15	Exploitation of molecular information in animal breeding	Utilization of chromosomal maps, microsatellites, biochemical and DNA markers and other molecular information for selection, breeding, and control of diseases
16	Feed intake and efficiency	Evaluation of feed intake traits and correlation between feed intake and other quantitative traits
17	Genotype by environment interaction	Discussion of effects of interactions between genotype and environment on the expression of traits
18	Management of genetic diversity	Assessment of genetic variability, characterization and conservation of indigenous animal genetic resources
19	Prediction of breeding values	Organization of data, genetic evaluation for animal traits and methodologies for prediction of breeding values
20	Subject support category	Statistical information applicable in animal breeding and genetics research

The paper characters were unevenly distributed with majority of the papers (77%) being empirical. Review and theoretical papers were few, only 10.9 and 12.1%, respectively. Given the definition of empirical papers used in this study, the results obtained were consistent with expectations. Most animal breeding and genetic research involves the use of observed or simulated data.

The majority of papers located their study in the "world" context (53%), followed closely by papers that located their study within a single country (44%). Those that located their study within a single continent were only 3%. This observation is realistic because most research findings are applicable across continents. Additionally, scientists preferred to research issues that affect more than just their local environments. Scientific objectives were therefore apparently aimed at solving either global or in-country problems.

Division of Papers among Research Topics and Continents

Table 4 shows the number and percentage of papers in each category. Among the topics analyzed, the major-

Table 2. List of the represented countries categorized by continent into developed and developing countries[1]

Developed countries				Developing countries			
Asia	Australia	Europe	North America	Africa	Asia	Europe	South America
Israel	Australia	Austria	Canada	Algeria	Bangladesh	Bulgaria	Argentina
Japan	New Zealand	Belgium	United States	Ethiopia	China	Croatia	Bolivia
Korea Rep		Cyprus		Benin	India	Czech Republic	Brazil
		Denmark		Botswana	Indonesia	Estonia	Chile
		Finland		Cameroon	Iran	Hungary	Colombia
		France		Egypt	Iraq	Lithuania	Cuba
		Germany		Gambia	Jordan	Macedonia, FYR	Mexico
		Greece		Kenya	Lao PDR	Poland	Paraguay
		Iceland		Libya	Mongolia	Romania	Peru
		Ireland		Malawi	Bhutan	Russia	Uruguay
		Italy		Morocco	Malaysia	Serbia	Venezuela
		Netherlands		Mozambique	Pakistan	Slovakia	West Indies
		Norway		Namibia	Papua New Guinea	Slovenia	
		Portugal		Nigeria	Philippines	Turkey	
		Spain		Senegal	Saudi Arabia	Ukraine	
		Sweden		South Africa	Sri Lanka		
		Switzerland		Tunisia	Syria		
		United Kingdom		Uganda	Thailand		
				Zimbabwe	Vietnam		

[1]Countries in which institutions, to which the author (if paper was by a single author), the first 2 authors (if a paper was by 2 authors), or the first 2 authors and the last author (if paper was by 3 or more authors), are located. The categorization into developed and developing countries was based on the World Bank's country classification (World Bank, 2006).

ity of papers were on breeding for meat production (34.89%), estimation of genetic parameters (34.52%), and design of sustainable breeding programs and strategies (22.24%). Other topics that were also highly researched included breeding for milk production (17.14%), exploitation of molecular information in animal breeding (16.65%), and detection of QTL (13.45%). Behavior and welfare (1.73%) and capacity building in animal breeding and genetics (0.37%) received little attention.

The frequency of continental contribution per category is shown in Table 4. There was a significant association between the various topics in animal breeding and genetics and continental representation (χ^2 = 361.902, $P < 0.001$). Europe contributed the most to all research topics except biochemical genetics and breeding for fiber and fur. Asia contributed the most to papers in biochemical genetics (35.37%), whereas Australia lead in research papers on breeding for fiber and fur (48.39%) reflecting the high population of small ruminants that produce fiber and fur in this continent. Africa usually, but not always, contributed the least to most research topics except for capacity building in animal breeding and genetics, disease resistance, exploitation of molecular information in animal breeding, feed intake and efficiency, management of genetic diversity, and the "subject support" category. Approximately 67% of papers on behavior and welfare originated from Europe. Asia and South America never gave attention to capacity building in animal breeding and genetics. In Africa, no paper reported on computer and information technology and prediction of breeding values.

Table 3. Authorship of papers per continent

Continent	No. of authors	Percentage
Africa	200	4.82
Asia	777	18.74
Australia	467	11.26
Europe	1,641	39.57
North America	641	15.46
South America	421	10.15

Nature of Research Partnerships

The N–N partnership was overwhelmingly dominant, covering 68.80% of research papers. This was expected because developed countries were the most represented. In contrast, the N–S partnership was the least pursued, as represented by only 8.23% of papers. The S–S partnership was represented by 22.97% of papers.

Table 5 shows the percentage of papers in each category by nature of research partnership. The various topics in animal breeding and genetics were significantly associated with the nature of the partnership (χ^2 = 145.868, $P < 0.001$). Within-topic comparison showed that N–N partnerships produced the most papers. For example, in the topic "breeding for meat production," N–N partnerships produced the most papers (61.86%), followed by S–S partnerships (29.70%). The fewest papers were from N–S partnerships (8.44%). Over 10% of papers in capacity building in animal breeding and genetics (16.67%), estimation of genetic parameters (10.14%), genotype by environment interaction (11.36%), management of genetic diversity (12.24%), prediction of breeding values (11.11%), and the "subject support" category were from N–S partner-

Table 4. The number and percentage of papers and the frequency of continental contribution in each category[1]

Paper category	No.	%	Frequency of continental contribution, %					
			Africa	Asia	Australia	Europe	North America	South America
Behavior and welfare	29	1.78	2.89	4.29	7.14	67.14	7.14	11.43
Biochemical genetics	117	7.19	1.52	35.37	11.59	31.10	16.46	3.96
Breeding for fiber and fur	51	3.13	3.87	15.48	48.39	23.23	1.94	7.10
Breeding for meat production	568	34.89	5.95	25.55	9.53	31.01	15.11	12.86
Breeding for milk production	279	17.14	1.81	18.25	5.99	47.91	16.02	10.03
Breeding for nonconventional or regional species	86	5.28	5.75	26.05	11.11	34.10	3.83	19.16
Capacity building in animal breeding and genetics	6	0.37	14.29	0.0	7.14	71.43	7.14	0.0
Computer and information technology	65	3.99	0.00	12.68	18.31	37.32	23.94	7.75
Design of sustainable breeding programs and strategies	362	22.24	5.70	24.21	16.58	29.81	14.55	9.16
Detection of QTL	219	13.45	1.83	18.11	13.12	44.19	19.93	2.82
Developmental genetics	44	2.70	0.00	19.28	14.46	43.37	22.89	0.00
Disease resistance	99	6.08	5.33	17.62	14.34	48.77	9.02	4.92
Estimation of genetic parameters	562	34.52	4.05	14.95	9.37	43.26	14.95	13.42
Experimental and observational quantitative genetics	68	4.18	5.62	11.80	8.99	43.26	23.60	6.74
Exploitation of molecular information in animal breeding	271	16.65	3.14	22.24	14.05	42.84	14.87	2.86
Feed intake and efficiency	54	3.32	7.04	6.34	20.42	36.62	25.35	4.23
Genotype by environment interaction	44	2.70	5.41	18.92	2.70	36.94	18.02	18.02
Management of genetic diversity	98	6.02	6.88	25.10	3.24	49.80	8.10	6.88
Prediction of breeding values	99	6.08	0.00	12.23	6.11	42.79	28.82	10.04
Subject support category	41	2.52	14.77	18.18	6.82	48.86	7.95	3.41
			$\chi^2 = 361.902$, 95 df, $P < 0.001$					

[1]Papers were assigned to up to 3 categories according to the most relevant subjects covered.

ships. The S–S partnership produced the most papers in the topic, breeding for nonconventional or regional species (46.51%). The N–S and S–S partnerships did not produce papers in the topics "behavior and welfare" and "capacity building in animal breeding and genetics," respectively.

DISCUSSION

Division of Papers Among Research Topics and Continents

A large number of papers were on breeding for meat production, breeding for milk production, estimation of genetic parameters, and design of sustainable breeding programs and strategies. This was expected because these topics are directly related to food production and efficiency of production, which conforms to the global objective of food security. The emphasis put on exploitation of molecular information in animal breeding and detection of QTL was not surprising and indicates the current trend of breeding animals taking into account the biological aspects of production and applying molecular genetics techniques to locate and exploit gene loci that have a major effect on quantitative traits.

Africa contributed the least to most research topics. Nevertheless, it is encouraging that African researchers at least contributed to all research topics given the trends in investments in agricultural research. Growth in agricultural research investments in Africa has stagnated over the past 2 decades (Bientema and Stads, 2004). Africa contributed more to capacity building in animal breeding and genetics and feed intake and efficiency than did Asia and South America. Asia and South America did not contribute to research topics on capacity building in animal breeding. However, this does not mean that research in this subject is nonexistent in these continents but that papers on this topic were either rejected or submitted to other conferences other than the WCGALP. It should be noted that authors from developing countries would not have the resources available in terms of infrastructure, animals, and funds to conduct different types of research, which could limit the types of studies that they could report. In addition, travel funds would be limiting for those from developing countries. More research into limitations for reporting the research is warranted.

There was evidence for continental prioritization of research topics. For example, Australia contributed the greatest to breeding for fiber and fur, reflecting the high population of small ruminants that produce fiber and fur on this continent. The continental prioritization of research topics indicates that certain agricultural problems may be more of a concern in one region as opposed to another. This is expected to continue because agricultural challenges are unique to regions. Continental prioritization should be used to develop research strategies that will contribute to the development of a more structured and defined understanding of genetics applied to livestock production. The fact that over 67% of papers on behavior and welfare originated from Europe suggests that advocates of animal welfare are concentrated in the European continent where intensive livestock production is common.

Table 5. The percentage of papers in each category and by the nature of the research partnership

Paper category	Nature of the research partnership[1]		
	N–N, %	N–S, %	S–S, %
Behavior and welfare	82.14	0.00	17.86
Biochemical genetics	69.23	6.84	23.93
Breeding for fiber and fur	64.71	7.84	27.45
Breeding for meat production	61.86	8.44	29.70
Breeding for milk production	68.82	8.24	22.94
Breeding for nonconventional or regional species	44.19	9.30	46.51
Capacity building in animal breeding and genetics	83.33	16.67	0.00
Computer and information technology	83.08	4.62	12.31
Design of sustainable breeding programs and strategies	69.61	7.73	22.65
Detection of QTL	85.32	7.34	7.34
Developmental genetics	79.55	6.82	13.64
Disease resistance	83.00	5.00	12.00
Estimation of genetic parameters	64.06	10.14	25.80
Experimental and observational quantitative genetics	82.35	7.35	10.29
Exploitation of molecular information in animal breeding	78.89	5.56	15.56
Feed intake and efficiency	81.48	1.85	16.67
Genotype by environment interaction	61.36	11.36	27.27
Management of genetic diversity	61.22	12.24	26.53
Prediction of breeding values	71.72	11.11	17.17
Subject support category	57.14	19.05	23.81

[1]N–N = North–North partnerships, defined as cooperation between and within developed countries; N–S = North–South partnerships, defined as cooperation between developed and developing countries; and S–S = South–South partnerships, defined as cooperation between and within developing countries.

Research areas in which more work is required include disease resistance, detection of QTL, exploitation of molecular information in animal breeding, and feed intake and efficiency. This work is particularly needed in Africa, Asia, and South America, because of their relationship with tropical stresses of disease challenges, heat, and poor nutrition. However, this should not be misconstrued to mean that sufficient research work has been done in the other topics not highlighted above. The highlighted topics are directly related to adaptation. An animal must be adapted to the tropical stresses to sustain certain levels of productivity. Luckily, adaptation to some of these stresses has a genetic basis and animals that are adapted can effectively be bred. This means that genes associated with adaptation can also be detected and exploited to improve animal productivity in these areas.

This study showed that genotype by environment interaction received little attention, with only 2.70% of papers reporting on it. The interaction between livestock and the environment finds importance in intensified systems of livestock production, in which pollution and animal welfare are issues of concern; this was mostly evident in the developed industries in Asia, Europe, and North America (Hoste, 2002). In developing countries of Africa, Asia, and South America, genotype × environment interaction is important where animal genetic resources are exported for use in another country with different environmental and management conditions as the source (Ojango and Pollot, 2002). This is common in developing economies where breeding programs are yet to be established and local programs are based on importation of genetic material. This calls for research into the design of sustainable breeding programs and strategies that enable small- to medium-scale livestock producers to benefit from the growing demand for animal products. In most cases, such livestock producers depend on indigenous animal genetics resources, whose potential has not been clearly determined. Such genetic resources need to be characterized and the genetic diversity within them assessed before programs for their use and conservation are designed and implemented.

Nature of Research Partnerships

Developed and developing countries seem to partner in research more with other countries within the same category. This has been necessitated by the similarity of challenges faced by livestock producers in countries within the same category. Partnerships between developed and developing countries were minimal. The reasons for this are not clear. Usually research partnerships between countries are formed to solve research problems that are either common in both countries or prevalent in one country that has no capacity.

The approaches used in livestock research have revolved around a combination of efforts by strategic partners within a country, between countries, and across continents. In effect, a variety of research partnerships have emerged with the aim of offering holistic solutions to problems affecting the realization of effective livestock production in the world. In many cases, such partnerships have received support from international do-

nors such as United Nations agencies (e.g., Food and Agricultural Organisation, United Nations Development Programme), the World Bank, and an array of development agencies, research institutions, and universities (Beintema and Stads, 2004).

The inadequacies faced by developing countries in terms of capacity to undertake priority research in livestock production can effectively be met by cross-border partnerships in research and development. National Agricultural Research Systems have been useful in expanding international research partnerships in developed and developing countries, which includes universities and research institutions (Hoste, 1999). For instance, in Uruguay, some forms of N–S partnerships were involved in the estimation of genetic parameters for scrotal circumference and 18-mo weight of Uruguayan Aberdeen Angus using Bayesian approaches (Urioste et al., 2002).

Gokhale and Duplan (2002) enumerated the village-level experiences on breeding of dairy cattle in medium to low-input production systems in India. The project was a partnership between France and India and interestingly, the funds were sourced from the Indian Council for Agricultural Research. This partnership produced useful conclusions that demonstrated the principles and guidelines for tailor-made genetic improvement programs suitable for improving milk yield in rural cattle, a lifeline for many rural populations in India.

Kahi and Nitter (2002) developed breeding schemes for pasture-based dairy production systems in Kenya and compared alternative breeding objectives and schemes under a 2-tier open nucleus using the young bull system. This project produced the prerequisites for the establishment of sustainable breeding programs for dairy production and formed the basis for numerous studies in breeding objectives development in Kenya (e.g., Kosgey et al., 2003, 2004; Menge et al., 2005; Rewe et al., 2006a,b).

Strategic partnerships between developing and developed countries are important, especially within the framework of capacity building. In this study, 16.67% of papers in capacity building in animal breeding and genetics were the result of N–S partnerships. Capacity building is important not only in animal breeding and genetics but in all aspects of agricultural research as a response to changing technologies and new discoveries (Malmfors et al., 2002). Through N–S partnerships, physical and human capacity development in agricultural research is expected to be experienced especially in developing countries. In fact, the interactive linkage between National Agricultural Research Systems in developed and developing countries under the catalytic role of some organizations; for example, institutes belonging to the Consultative Group on International Agricultural Research (CGIAR), has been shown to facilitate speedy development in human and physical capacity (Malmfors et al., 2002). This is important for economic development in these countries, where agriculture is the backbone of the respective economies (FAO, 2003; World Bank, 2003).

IMPLICATIONS

This study has presented evidence about research partnerships in animal breeding and genetics. The bulk of the papers represented research done through North-North (i.e., within developed countries) partnerships. The least-utilized partnership was that between developed and developing countries. Papers presented at the World Congresses of Genetics Applied to Livestock Production are as a result of on-going and completed research work; therefore, these results may be taken as indicative of the research partnerships in the last decade. This study points to a real lack of global science, and should serve as an incentive and justification for more focused efforts on increasing levels of scientific cooperation between researchers in developed countries and their colleagues in the developing countries. North–South partnerships can result in sound research and development goals. Therefore, mechanisms need to be put in place to encourage more North–South partnerships as an indirect means of inducing or speeding up agricultural, and consequently, economic growth in developing countries.

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