Technical Challenges in Evaluating Southern China's Forage Germplasm Resources

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The 22nd International Grassland Congress (Revitalising Grasslands to Sustain Our Communities) took place in Sydney, Australia from September 15 through September 19, 2013.
Proceedings Editors: David L. Michalk, Geoffrey D. Millar, Warwick B. Badgery, and Kim M. Broadfoot
Publisher: New South Wales Department of Primary Industry, Kite St., Orange New South Wales, Australia

Technical challenges in evaluating southern China's forage germplasm resources

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Abstract. The present status of the collection, conservation and utilisation of the pasture germplasm in tropical and subtropical zones in China is reviewed. The Tropical Pasture Research Centre (TPRC) of Chinese Academy of Tropical Agricultural Sciences (CATAS) has been engaged in this research since the 1940s. A low temperature gene bank, an *in vitro* plant library and a nursery station have been established. In total, 5890 indigenous fodder materials belonging to 478 species, 161 genera and 12 families have been surveyed and collected in South China; 1130 exotic materials belonging to 87 species, 42 genera of grasses and legumes have been introduced and conserved; 3769 materials from 301 species, 127 genera, 12 families have been conserved in the seed bank; 482 materials belonging to 6 species, 6 genera, 3 families have been propagated in vitro, and 388 materials belonging to 10 species, 8 genera, 3 families grown in the plant preservation nursery. Suggestions are made for developing and utilising southern Chinese grassland resources.

Keywords: Forage germplasm resources, tropical and subtropical regions, assessment collection, conservation, utilisation.

Introduction

China's tropical and subtropical regions are located between 15° to 33°N and 100° to 125°E. The region has 121m people, 13% of the total population in China (Liu 2008) and covers 260 million ha, including the entire area of the Provinces of Guangdong, Hainan, Guangxi, Hunan and Fujian, most parts of Yunnan, Guizhou, Jiangxi, Zhejiang and Sichuan, the southern area of Hubei and Anhui; and small districts of south-east Tibet and south-west Jiangsu Province. The tropical area accounts for 5% of the south China zone, predominantly in the southern district of Guangdong (Leizhou Peninsula) and all of Hainan Province. Arable land occupies 28 million ha (10.7% of the region) forests 90 million ha (34.6%) and grasslands 79 million ha (30.4%).

This is a warm climate area with plentiful rainfall without an obvious winter and separate wet (generally from May to October) and dry seasons. The average annual rainfall is 1200-2500 mm, the average temperature is 20 - 26°C and the accumulated temperature above 10°C is 7900°Cdays. It is more mountainous in northern and western areas with upland and river plain topography in the coastal areas of the southeast. The mountainous and upland area covers more than 30% in this region and is not suitable for other cash crops except forage system production. Forage plant resources are abundant in cleared areas. The current status of vegetation is secondary forest (coniferous, broad-leaf, shrub-land and coppiced forests) grassland and agricultural land. The grasslands includes savanna, shrubland, coppice forest and arable land sown with exotic legumes and grasses. Most of the grasslands are distributed in small areas belonging to smallholder farmers where there is a potential for forage intercropping with cash-crops, rubber and fruit plantations. Most of south China experiences good climatic conditions with enough heat and water to support good growth of forage plants throughout the tropical and subtropical regions. Despite the degradeation resulting from fire, overgrazing, the cutting of vegetation for fuel and use as a source of organic matter input for cropland, forage germplasm remains a valuable resource. This paper reviews the scale of forage plant resources in southern China, the programs to identify, evaluate and utilise these forages and concludes with a discussion of current issues and solutions.

Surveys of tropical and subtropical forage genetic resources

In the past 50 years, 6707 forage and feed plant species belonging to 1545 genera in 246 families were surveyed. In 1978-1990, Chinese Academy of Agricultural Science (CAAS) collected 4125 species of the original and natural forages for possible cultivation and breeding, belonging to 879 genera within 127 families; 972 species from 173 grass genera and 646 species from 81 legume genera. The species came from Hainan (1067) Guangdong (482) Yunnan (698) Guizhou (1400) Sichuan (232) Jiangxi (733) Anhui (255) and Hubei (931). In 1980, the National Grassland Survey identified more than 1000 species belonging to 190 grass genera and 791 species belonging to 120 legume genera on natural grassland areas of the southern 14 provinces (see references on *Flora of Fujian*, *Guangdong*, *Hainan and Yunnan*). In south China, there are 4680 known forage species (Table 1) among which Angiosperms are the biggest category, mostly Dicotyledons (240 families) and Monocotyledons (22 families). The most highly regarded forage plant resources in south China include 687 species, principally 364 grass species and 87 legume species. Among these indigenous species, 354 species are unique

Table 1. Composition of indigenous forage and feeding plant in south China.

Category	Family	Proportion of total family	Genera	Proportion of total genera	Species	Proportion of total species
Fern	14	5.3	31	2.3	46	1.0
Gymnosperm	8	3.1	16	1.2	63	1.4
Angiosperm	240	91.6	1303	96.2	4571	97.7
dicotyledon	218	83.2	1068	79.1	3704	79.2
monocotyledon	22	8.4	235	47.4	567	18.5
Total	262	100.0	1350	100.0	4680	100.0

Table 2. The category of forages and feeding resources in south China.

Category of forage resource	Family	Genera	Species
Indigenous species	123	587	1432
Peculiar species	85	128	354
Rare and endangered species	53	120	152
Productive species	25	243	687

forage plant species, including 67 grass species and 45 legume species (Table 2), some are used for livestock production (Wu 1961; Liu 2000).

The variable topography and climate in Hainan Island has produced the most tropical species within the rich flora in China, 25000 species of higher plants. CAAS first surveyed the original and indigenous forage plant resources in 1983, and recorded 119 species (Li 2000; Shi *et.al* 2008). Hainan provincial research units then surveyed forage resources in 1986 and recorded 567 species. Subsequently CATAS in Hainan recorded 1048 forage plant species in 1993. 242 species of grasses genera were investigated and details recorded including morphological characteristics, habitat and eco-geographic distribution during 2004 to 2009. Some of these forage germplasm resources are species introduced from outside Hainan (Wu 1961; Flora of Guangdong 2007; Flora of Yunnan 2003; Flora of Fujian 1995; Liu 2000; Yin 2008).

Forage germplasm resource exploitation is based on collection and effective conservation as part of a long-term strategy to identify, evaluate, and utilise forages. So far about 6000 forage materials have been collected, most are conserved and only a limited number have been evaluated for their forage potential. There are still many other plant materials to be conserved and evaluated. For example, it is reported that the indigenous forage and feeding plant resources in south China comprise 123 families, but only 12 families have been collected. According to the *Flora's of Hainan, Guangdong, Guangxi and Fujian*, there are 364 grass species in 92 genera, but only 38 species has been collected and conserved. Future work in south China will place more emphasis on collecting rare, endangered and individual forages germplasm resources, including those with pest and disease resistance.

Methods for collection, reproduction and conservation

Collection and investigation

The collection of indigenous forage includes three stages: finding and identifying forage genera and species; ecological descriptors of where plants grow – local vegetation type, soils, topographical features, climatic data; and census data on location (latitude, longitude, altitude, map reference) registration numbers, collector *etc.* The investigation of indigenous forages uses four stages: field investigation including visiting local farmers; data descriptors of forages; planting in greenhouse, reproduction, vegetative multiplication and preliminary evaluation; and field investigations. Collection and investigation processes overlap. Sites for collection will sometimes be based on experience or every 30-50 km along accessible roads or tracks. Collectors aim to obtain mature seeds where possible, or else tillers, stems, seedlings, tubers or other propagule material. Where exotic forage genetic resources are introduced, the aims are to obtain similar levels of background information and to maintain bio-security.

Reproduction

The number of seeds collected in the field is usually limited and hence there is the need to produce enough seeds for the conservation and further evaluation of material. Reproduction is done in the green or shade house or in the field. Seeds will be treated to enhance germination as while seed dormancy may be low some groups have hard seed. Legumes and grasses are sometimes propagated vegetatively.

Conservation

The storage of seeds is the more efficient way to conserve tropical and subtropical forage germplasm resources. Seeds are stored under low temperature, humidity and oxygen to increase their longevity. Long-term and short-term storage are used at TPRC, CATAS. Long-term storage uses -20~-15°C, RH 12-15% which should maintain viable seeds for >25 years; short-term storage uses 0-5°C, RH 12-15% to keep seeds for <5 years. Seeds are sealed in aluminium foil bags containing ~15000 seeds in each. Germination and water content of seeds may be tested before storage and again every 3-5 years.

Current status of forage genetic resources evaluation and conservation

By 2006, the National Animal Husbandry and Veterinary Service, Ministry of Agriculture (MOA), had evaluated national forage germplasm resource conservation for more than 10 years. The national forage germplasm resources conservation system had been established, including one central gene bank, two duplicate gene banks, 15 nurseries, and 10 collaboration teams from different ecosystem-regions in China. The central seed bank of state forage germplasm resources centre has collected 9500 materials from 1000 species, 411 genera and 67 families, of forage germplasm resources from 1998 to 2006 from all over the

Table 3. Families of tropical and subtropical regional forage genetic resources in south China.

Family	Genera	Species	Share	Indigenous species	Indigenous share	Exotic species	Exotic share
Fabaceae	72	246	3390	210	2852	36	538
Poaceae	89	252	3078	224	2840	28	238
Compositae	3	3	7	3	7		
Amaranthaceae	2	6	87	6	87		
Euphorbiaceae	2	2	385	2	31	1	354
Malvaceae	1	1	2	1	2		
Sapindaceae	1	1	9	1	9		
Urticaceae	1	1	1	1	1		
Cyperaceae	13	21	47	21	47		
Convolvulaceae	1	1	1	1	1		
Labiatae	1	1	1	1	1		
Acanthaceae	1	1	1	1	1		
Cruciferae	2	3	5	3	5		
Polygonaceae	1	3	6	3	6		
Total	190	542	7020	478	5890	65*	1130

Note: * 87 species have been introduced and conserved, in which 65 species are exotic and 23 species are both indigenous and exotic such as Cassava (Manihot Mill) including indigenous and exotic materials, the same as genera.

country. To date, more than 18000 materials have been collected and conserved in the central gene bank, and the agronomic characteristics of more than 12000 materials have been evaluated; the productivity of more than 1500 materials has been identified and evaluated. 45 grasses and 28 legumes have been identified with good potential for forage, 96 plant lines have become the basis for recent forage breeding.

Forage genetic resource have been under severe threats resulting from: (1) natural factors, including environmental and climate change, greenhouse effects, ozone increases, fire, soil degeneration and serious pollution; (2) infrastructure development, such as building of roads, rail, mining, new industrial developments, transformation of forests or grasslands into new cropland, the cutting of vegetation for fuel, urbanisation, overgrazing and other activities that destroy farmland; (3) scientific and technological innovation, including the planting of new varieties, the application of fertiliser, the mechanisation of agriculture; and (4) the replacement of some old locally evolved varieties by introduced species, cultivars and agronomic practices (Jiang 1996; Zhang 2003; Wang 2007; Li 2000; Zhao 2009). The TPRC, CATAS has taken up the tropical and subtropical forage resources' collection and conservation from 1940 to now, 5890 indigenous materials belonging to 478 species, 161 genera, 12 families have been surveyed and collected in Hainan, Guangdong, Guanxi, Fujian and South Yunnan provinces.

Tropical areas only account for 5% of south China; the tropical indigenous plant resources are very limited. To date cultivated forage varieties have come mostly from four centres of origin in the world (He 1986). Tropical African savannah is the centre of many tropical cultivated grass fodder varieties such as bluestem (*Andropogon* L.) panic grass (*Panicum* L.) pennisetum grass (*Pennisetum* Rich.) bristlegrass (*Setaria* Beauv.) and signal grass (*Brachiaria* Griseb.). Tropical America is the centre of fewer cultivated tropical grass varieties such as carpet grass (*Axonopus* Beauv.) paspalum (*Paspalum* L.) and gama grass (*Tripsacum* L.). Tropical America, however, is the centre of many tropical cultivated forage legume varieties, such as stylo (*Stylosanthes* Sw.) butterfly pea (*Centrosema* Benth.) large-wing bean (*Macroptilium* (Benth.) Urban.) leucaena (*Leucaena* Benth.) and Calopogonium (*Calopogonium* Desv.). Tropical Africa is the centre of other tropical cultivated legume varieties such as cowpea (*Vigna* Savi), indigo (*Indigofera* L.) and alysicarpus (*Alysicarpus* Neck. Ex. Desv.) (Liu 2000; Yu 2006).

The introduction of tropical forages into China started as early as the 1940's when elephant grass (*Pennisetum purpureum* (Rich.) Schum.) was first introduced from South-east Asian countries. In 1982 the NSW Department of Primary Industries introduced and tested a wide range of tropical and sub-tropical grasses and legumes in Hainan (Michalk *et al.* 1993a, b) and Guangdong (Michalk and Huang 1994a, b). After that TPRC began to gradually introduce forage genetic resources from the International Centre for Tropical Agricultural (CIAT), Australian Centre for International Agricultural Research (ACIAR), Brazilian Agricultural Research Corporation (EMBRAPA) and others. Now, altogether 1130 exotic materials, 87 species, 42 genera, of which 12 genera are exotic, have been introduced and conserved (Table 3).

In 2009, TPRC launched a project for the conservation of tropical and subtropical forage germplasm resources. As the leading unit in south China, it established one seed gene library using low temperature conservation, one *in vitro* conservation library and one nursery station for plant propagation. The seed copy bank of tropical and subtropical forage germplasm resources has collected and conserved 3769 materials, the conservation library has 482 materials and the nursery station has 388 materials (Table 4).

State of forage germplasm resources

The grass industry in South China has achieved productive results in the cultivation and breeding of forage species from introduced and native germplasm, grassland improvement, prevention of disease and insect pests, intercropping between fruit or forest plants, coastal dune stabilisation and their utilisation for livestock. In 1986, the National Approval Committee for Pasturage Species held its first meeting to approve forage species and by 2012, 453 cultivars had been registered, of which 120 cultivars are suitable for southern China; 50 legumes and 70 grasses (Liu 2008). The TPRC, CATAS has successively selected

Table 4. The composition of tropical and subtropical forage genetic resource in different conservation types.

Types of Conservation	Family	Genera	Species	Shares
Low temperature conservation in genebank at TPRC, CATAS	Fabaceae	67	204	3161
	Poaceae	35	56	443
	Compositae	2	3	7
	Amaranthaceae	2	6	87
	Sapindaceae	1	1	9
	Convolvulaceae	1	1	1
	Cruciferae	2	3	5
	Polygonaceae	1	3	6
	Cyperaceae	13	21	47
	Labiatae	1	1	1
	Acanthaceae	1	1	1
	Malvaceae	1	1	1
	Total	127	301	3769
Conservation in vitro at TPRC, CATAS	Fabaceae	4	4	21
	Poaceae	1	1	61
	Euphorbiaceae	1	1	400
	Total	6	6	482
Conservation in nursery at TPRC, CATAS	Fabaceae	1	1	6
	Poaceae	6	8	58
	Euphorbiaceae	1	1	324
	Total	8	10	388

and bred and released 19 cultivars (Table 5). These varieties have been used across the southern and southwest provinces in China. They are not only used for grazing and producing high-quality hay and grass meal, but also widely used for green manure, young rubber tree gardens, coverage of orchard floors, conservation of soil and water, fixing of coastal sand into soil as well as the environmental greening and beautification, which expands the function and role of tropical pasturage and brings new concepts to the development of the grass industry in South China.

Stylosanthes guianensis Reyan No.2 has been planted over 2 million ha in Hainan, Guangdong, Guangxi, Hunan, Jiangxi, Jiangsu, Yunnan, Guizhou, Sichuan, Fujian and other regions. *Pennisetum americanum* (Wang grass Reyan No.4) has been planted over 10m ha in Xinjiang, Beijing, Hubei, southern China and the southwest and is used as a solution to the problem of shortage of winter feed in parts of northern region. The Fujian Agricultural and Scientific Institution have bred and released other productive cultivars of *Cassia rotundifolia* and *Brachiaria* hybrid No.1. Due to their advantages such as fast-growing, high-coverage, strong ability of fixing nitrogen, good pest and disease resistance and higher nutrition, they have obvious superiority in the conservation of water and soil, ecological and soil fertility restoration, and nutritive value. The Yunnan Research Centre for Beef Cattle and Pasturage has released seven cultivars (Weichite Eastern Pennisetum, Haifa white clover, white clover, and Shafulei Kenya), which are planted over 8 million ha in Yunnan, Guizhou and neighbouring areas.

The problems

The danger of losing tropical forage resources

The acknowledged degradation problems in Chinese grassland ecology are a major threat to the loss of indigenous forage species. With the rapid development of the economy in south China, grassland, forest and rangeland areas have been considerably reduced in area and what remains is under increased pressure to feed the large population. Some varieties and genotypes of good forage species are disappearing due these pressures, threatening genetic diversity. Conservation practices are by necessity a compromise, which means only some genotypes will be preserved. Field evaluation of genotypes lags considerably behind the accession of material such that valuable genotypes may not be tested or could be lost in storage. Genetic drift/loss is a real risk with cross-pollinated species (Yan 2008). A consequence of these factors is that forage species do need to be maintained in the wild and collections renewed at intervals.

The limited use of collections

The work on the identification and utilisation of the tropical pasture germplasm has not been enough to thoroughly appraise this resource and to maximise gains. There is still only a general understanding of what ecotypes are in the collections and a poorer understanding of any special traits that may be there. Breeding work has been limited. The cultivars released, while an improvement on existing material, have only had limited selection, though it is considered that the total resource is a rich one.

Limitations in conservation and conservation technology

The strategy adopted to collect and conserve material is relatively standard and designed to handle larger amounts of material with some efficiency. It has not been possible to develop and use more innovative conservation techniques, especially for those species that may have unusual reproductive strategies. It is anticipated that techniques such as asexual reproduction, tissue culture, cloning and pollen storage as well as advanced techniques for storing DNA *etc.*, will need to be developed and used to maintain the collections and their genetic diversity (Yan 2008). These techniques would aim to speed up the identification and utilisation of improved material.

Lack of the communication consciousness and mechanism

Germplasm is a common good and should belong to the community. Any benefits from exploiting these resources

Table 5. Varieties released by CATAS.

Cultivar	Year of release	Extension area	Adapted to
Leucaena leucocephala cv. Reyan No.1	1991	Hainan, Yunnan	poor soils, drought, waterlogging
Stylosanthes guianensis cv. Reyan No.2	1991	Hainan, Yunnan	poor acid soils, drought, waterlogging
Brachiaria decumbens cv. Reyan No.3	1991	Hainan, Guangdong	poor soils, drought, waterlogging
Pennisetum americanum cv. Reyan No.4	1998	Each province of south China	poor soils, drought, waterlogging
Stylosanthes guianensis cv. Reyan No.5	1999	Hainan, Yunnan	acid soils, cold
Brachiaria brezantha cv. Reyan No.6	2000	Hainan, Yunnan	poor soils, drought, waterlogging
Stylosanthes guianensis cv. Reyan No.7	2001	Hainan, Yunnan	resistance to disease
Panicum maximum Jacq. cv. Reyan No.8	2000	Hainan, Yunnan	poor acid soils, drought, waterlogging, shade
Panicum maximum Jacq. cv. Reyan No.9	2000	Hainan, Yunnan	poor acid soils, drought, waterlogging, shade
Stylosanthes guianensis cv. Reyan No.10	2000	Hainan, Yunnan	poor acid soils, drought, shade
Paspalum atratum cv. Reyan No.11	2003	Hainan, Yunnan	acid and poor soils
Arachis piotoi cv. Reyan No.12	2004	Hainan, Yunnan	poor acid soils, shade
Stylosanthes guianensis cv. Reyan No.13	2003	Hainan, Yunnan	drought, poor acid soils - resistance to disease
Brachiaria dictyoneura Stopf. cv. Reyan No.14	2004	Hainan, Yunnan	acid soils, shade
Brachiaria ruziziensis G.& E. cv. Reyan No.15	2005	Tropical area, annual average rainfall >750mm	poor soils, drought
Desmodium ovalifolium Wall. cv. Reyan No.16	2005	Tropical area, annual average rainfall >1000mm	poor acid soils, shade, drought
Pueraria phaseoloides (Roxb.) Benth. cv. Reyan No.17	2006	Hainan, Yunnan	shade, poor soils, drought, waterlogging
Stylosanthes guianensis (Aubl.) Sw. cv. Reyan No.18	2007	Hainan, Yunnan	shade, poor soils, drought
Panicum maximum Jacq. cv. Reyan No.19	2007	Hainan, Yunnan	shade, poor soils, drought, waterlogging
Stylosanthes guianensis Sw. cv. Reyan No.20	2010	Hainan, Yunnan, Guangdong, Fujian, Guangxi	resistance to disease, tolerance to acid soil, drought, shade
Stylosanthes guianensis Sw. cv. Reyan No.21	2011	Hainan, Yunnan, Guangdong, south Fujian, Guangxi, south Sichuan	low temperature, drought

should be available to the community – be it at a country, provincial or local level, depending upon prevailing opinions. Intellectual property rights in many places are still to be resolved. By retaining the rights of forage resources in public hands there is more chance of the wider community benefiting.

Suggestions

Strategies to survey, collect and introduce forage resources

Any selection and breeding program needs to have significant genetic diversity to maximise the chance of producing good cultivars. Programs need to expand to include more exotic material as well as local collections of the same species.

Increase germplasm innovation

Research needs to identify those traits that significantly enhance the quantity and quality of forage produced. A range of techniques, including genetic engineering, then need to be used to produce germplasm for testing and eventual release.

Strengthen use of new cultivars with independent intellectual property rights

There are few tropical forage cultivars with independent intellectual property rights. This needs to be encouraged to stimulate cultivar development.

Promote sharing of resources

Scientific progress depends upon the sharing of information. The development of forage resources in southern China would benefit from sharing of these genetic resources with the goals of conserving material and producing more productive cultivars for animal forage. Appropriate protocols for sharing material need to be developed.

References

Flora of Fujian (1995) Science and Technology Commission of Fujian Province, Fuzhou: Fujian Science and Technology Press.

Flora of Guangdong (2007) South China Botanical Garden, The Chinese Academy of Sciences, Guangzhou: Guangdong Science and Technology Press.

Flora of Hainan (1979) South China Institute of Botany, Chinese Academy of Sciences, Beijing: Science Press.

Flora of Yunnan (2003) Kunming Institute of Botany, Chinese Academy of Sciences, Beijing: Science Press.

He CZ (1986) An introduction of technology on forage germplasm resource research. *Grassland and Turf* **4,** 50-53.

Jiang YQ (1996) The achievements and prospects of research on forage germplasm resources in China. *Journal of Northeast Normal University* **13,** 93-96.

Li XF (2000) A thought of forage germplasm resource perseveration and utilization. *Grassland of China*, **5(**2), 74-75.

Liu GD (2000) *Flora of Hainan tropical forage*. Beijing: Chinese Agriculture Press.

Liu GD, Michalk DL, Bai CJ, Yu DG, Chen ZQ (2008) Grassland development in tropical and subtropical southern China. *The Rangeland Journal* **30**(2), 255-270.

Michalk DL, Fu NP, Zhu CM (1993a) Improvement of dry tropical rangelands in Hainan Island, China: 1. Evaluation of pasture legumes. *Journal of Range Management*, **46**, 331-339.

Michalk DL, Fu NP, Zhu CM (1993b) Improvement of dry tropical rangelands in Hainan Island, China: 2. Evaluation of pasture grasses. *Journal of Range Management*, **46**, 339-.345

Michalk DL, Huang ZK (1994a) Grassland improvement in subtropical Guangdong Province, China: 1. Evaluation of pasture legumes. *Tropical Grasslands*, **28**, 129-138.

Michalk DL, Huang ZK (1994b) Grassland improvement in subtropical Guangdong Province, China: 2. Evaluation of pasture grasses. *Tropical Grasslands*, **28**, 139-145.

Shi WG, Li ZY, Wang YQ (2008) Documentation concordance and share of forage germplasm resources. *Journal of Plant Genetic Resources* **9(**4), 561-565.

Wang TM, Zhang JN, Lu XS (2007) Development strategies of forage germplasm resources in China. *Chinese Journal of Grassland* **129(**13), 104-108.

Wu ZY (1961) *Flora of China*. Beijing: Editorial Committee of Chinese Academy of Sciences.

Yan XB, Wang CZ, Guo YX (2008) Storage, utilization and conservation of forage germplasm in China. *Pratacultural Science* **25(**12), 85-91.

Yin J, Sun Z, Wei Q (2008) Current status and prospect of forage germplasm resources in Yunnan province. *Pratacultural Science* **25(**10), 88-94.

Yu DG, Liu GD, Bai CJ (2006) A survey on indigenous fodder germplasm and study on indigenous fodder development and utilization. *Chinese Agricultural Science Bulletin* **122(**5), 416-420.

Zhang JY, Yuan QH, Zhang WS (2003) The advances in study on forage germplasm resources and its genetic diversity in China. *Grassland of China* **8(**2), 59-65.

Zhao LX (2009) The potentiality and countermeasures of collection, valuation and utilization of excellent forage germplasm resources in China. *Acta Agrestia Sinica* **1,** 413-419.