A scientific contribution to legume studies during the fifty years of the Institute of Animal Science

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Papers published in the Cuban Journal of Agricultural Science between 1967 and 2013 dealing with creeping, seasonal and shrub legumes are reviewed. Among them are those about the state of the art on this subject, representing a total of 257 contributions. Outstanding are the investigations on *Neonotonia wightii*, *Leucaena leucocephalala* and the multiple associations of creeping legumes with grasses, which allowed defining technologies for their establishment and exploitation in grazing systems for animal production. Work developed with this plant family also contributed with a technology for biomass production of seasonal legumes for feeding non-ruminant animals.

Key words: *creeping legumes, shrub, tree*

INTRODUCTION

In the majority of the tropical regions, the necessary natural resources for promoting the agricultural development undergo a serious decline jeopardizing the fulfillment of the vital needs of future generations, with the known risks for the ecological, social, political and economical stability in developing countries.

Right from the start, Cuban cattle production envisaged the use of pastures and forages as main feeding sources to the cattle for milk or meat production. Grasses and legumes were in the plant kingdom, the families of highest potential for covering these objectives. However, grass monoculture, mainly Digitaria, Pennisetum, Megathyrsus and Cynodon genera, among others, was established in all livestock production areas of the country, while the utilization of legumes did not attain generalization in the different production systems.

In this paper are assessed the different research phases in the legume field and their utilization in plant and animal production developed by the Institute of Animal Science, since its creation in 1965 until 2013. Results of this research study which have been published periodically in the Cuban Journal of Agricultural Science are compiled in this review.

BACKGROUND

In the first years of legume research, the approach developed in countries such as Australia was applied. Studies realized were led to the validation of these technologies under our conditions. It was not until the end of the seventies of the past century that studies were conducted according to the climate, soil and requirements of the developing Cuban cattle production conditions.

The first two investigations on the legume topic were published in the Cuban Journal of Agricultural Science at the end of sixties of the XXth century (Boado 1969 and Herrera *et al.* 1969). In the first five years of the seventies these contributions increase, but mainly with alfalfa species (*Medicago sativa*).

Studies with this species dealt with subjects related with seed production (Zambrana 1971a and 1972b), agricultural technique (Zambrana 1970 and 1972a) and biomass production (Zambrana 1971b, 1972b, 1973ab and Zambrana and Oduardo 1972). To a lesser extent weed experiments (Tomeu 1970, Zambrana 1971c and 1973c and Sistachs and León 1974) and inoculation (Sistachs 1974) were developed.

At this stage, the first studies of biomass production with tropical legumes *Pueraria phaseoloides* and *Cajanus cajan* (Febles and Padilla 1970 and Suárez and Herrera 1971) are reported and starts the assessment of the utilization of grass and grass legume associations under grazing conditions (Febles and Padilla 1972).

From 1974, a new approach for the research plan of Institute of Animal Science gave priority to the study of tropical legumes. Since 1975, research mainly with creeping species start. Studies with treelegumes began in 1979. The most studied species were *Neonotonia wightii* and *Leucaena leucocephalala*, respectively

CREEPING LEGUMES

Research between 1975 and 1989 were directed to the exploitation in pure cultures and managed in protein banks for animal feeding. In this period were defined concepts for its better establishment and utilization in

animal feeding which were extended to other perennial legume species.

The biological fixation of the atmospheric nitrogen in *N. wightii* systems was investigated by Sistachs and Frías (1980) who gave priority to the evaluation of rhizobium strains, type of soil and seed pelletizing methods. Later, López and Paretas (1982) related these topics directly to biomass production.

Other outstanding studies on this species dealt with the different establishment phases (Ruiz and Ayala 1983, 1985 and 1987 and Ruiz *et al.* 1986). Under this wide concept of legume management, defining the productive life of these systems, also investigation was undertaken on seed production (Febles and Padilla 1977 and Febles *et al.* 1983), weed control (Sistachs *et al.* 1977) and, to a lesser extent, chemical fertilization (Ruiz *et al.* 1976 and Ruiz y Ayala 1978).

First productive results with the use of protein banks with Glycine were published by Pereiro *et al.* (1983) and Pereiro and Elías (1987) related to the substitution of concentrate feeds and the study of the frequency of restricted grazing in milk production systems. Cino *et al.* (1996) complemented them with the economical evaluation of the dairy systems using protein banks of Glycine. During this period were also reported the first results of the studies on animal physiology of animals supplemented with Glycine protein banks for milk production (Galindo *et al.* 1985).

Marrero *et al.* (1989) reported the performance of developing Holstein females supplemented during grazing with Glycine protein banks. In an isolated way the utilization of protein banks with this species for gestating cows is shown (García López and Pereiro 1988).

With similar approach, experiments started in this period with grass and creeping legumes associations (Monzote 1977 and Monzote *et al.* 1982). The management of associated grasslands and its effect on grassland persistency and on the productive performance of beef cattle were subjects investigated (Monzote *et al.* 1984 and 1986) and always characterized by the utilization of only one legume in the association. It was also studied the free access or not of the animals to the area of the protein bank (Ruiz *et al.* 1991 and Castillo *et al.* 1991).

Knowledge achieved in this subject marked the beginning of another research phase, dealing with the use of various legumes in the association. This new concept in the studies took place in the first decade of this century and it was related to the use of multiple legume mixtures associated with one grass (Ruiz *et al.* 2005). At the same time the first studies on the topic began to be published. The number of legumes, grass-legume row relationship, weed control, the putting into exploitation and animal management were investigated giving place to the implementation of technologies increasing the persistency and productivity of these grasslands (Ruiz *et al.* 1994, 2006, 2007a, 2007b, 2007c and 2009).

Functioning during this phase of the institutional group of legumes, also allowed essays on ruminal physiology (Elías *et al.* 2006 and Galindo *et al.* 2009) and the identification of soil stability indicators in areas with these associations (Lok *et al.* 2011). From the point of view of animal production, protein-energy supplementation (Castillo *et al.* 2003 and Díaz *et al.* 2012) and the performance of different breeds for meat production (Díaz *et al.* 2008a and 2011) contributed to close the productive cycle to the soil-plant-animal relationship. Also, economical and financial indicators of these systems were studied (Cino and Díaz 2010).

TREE LEGUMES

Studies with these plants were initiated in the seventies of the past century. *Leucaena leucocephalala* was the pioneer species and that of highest research results today in the institution. The first papers on this species started to be published since 1985, although the highest number of them was published between 1990 and 2009.

A multidisciplinary group for legumes studies, in 1985, was created at the Institute of Animal Science and its steady functioning lasted until 2004.It propitiated an increase in the number of articles published because the amount of researches of different specialties increased and the result was the obtaining of integral technologies with capacity to be introduced in Cuban cattle areas, as well as in other countries such as Mexico –Pastures and Forages, Digestive Physiology, Management and Ruminant Production department from this group. Also, in a punctual way, Management and Monogastic Production and Biomathematics integrated the group.

First studies dealt with the assessment of *L. leucocephala* germplasm introduced from Brazil to know its potential for seed production under Cuban conditions (Febles *et al.* 1991). Likewise, Ruiz *et al.* (1992) analyzed comparatively the growth and development of these materials. Lazo *et al.* (1994) compared three leucaena species associated with Bermuda grass-68 (*Cynodon dactylon*) under grazing conditions with growing females. Later on, Febles *et al.* (2007) evaluated the performance of the native and foreign germplasm of 40 tree legumes and proposed a practical methodology for its evaluation, selection and use in different types of silvopastoral systems.

The possibility that legumes, such as leucaena, have of fixing atmospheric N through the symbiosis with bacteria of Rhizobium genus was another of the research topics to which prior attention was given (López

and Taboada 1983). In an important way, studies were centered on each one of the phases for the successful establishment of the shrub species in the grazing system. The sowing time and depth, the tree-grass relationship, intercropping in grasslands, practices for weed control and plant height for starting grazing were decisive topics for proposing the establishment methodology for this species (Ruiz *et al.* 1988, l989, 1990, 1996 and 1997 and Padilla *et al.* 2001a).

Studies on ruminal microbiology (Galindo *et al.* 1995a) of animals including in their diets *Leucaena leucocephalala* marked a new chapter in the technological conception of these systems. Research carried out by Galindo *et al.* (1995b) demonstrated mimosine and DHP degradation in the rumen and made feasible the use of this tree species in 100 % of the grazing area. Delgado *et al.* (1996) evaluated the effect of different inclusion levels of leucaena on consumption and digestibility of the fiber while La O *et al.* (1997) and La O *et al.* (2001ab) characterized the bromatological composition and the chemical components of eleven varieties of these species introduced from Colombia.

In the management and exploitation of silvopastoral systems with leucaena were studied the factors involving biomass production. These experiments not only considered the productivity of the plant components of the system, but also incorporated the chemical (Alonso 2004 and Lok *et al.* 2007), physical (Lok *et al.* 2007) and biological characteristics of the soil (Alonso *et al.* 2005a and Lok *et al.* 2006); the pruning methods (Alonso *et al.* 2003), shade and its space distribution (Alonso *et al.* 2006) and the biodiversity associated with the system (Alonso *et al.* 2004 and 2005b). In this way, a more integral vision of the biomass production concept was offered and the productive development of silvopastoral system was characterized.

The tree effect on the bromatological composition of the grass stratum (Alonso *et al.* (2008) and productive stability of the grassland (Ruiz *et al.* 2010), as well as the management and pest control studies (Barrientos *et al.* 1991), beneficial entomofauna associated with leucaena systems (Valenciaga *et al.* 1999 and Valenciaga and Mora 2002), spatial and seasonal dynamics of *Heteropsylla cubana* (Valenciaga *et al.* 2005) and the determination of infestation by phytophagous insects in agroecosystems with leucaena (Valenciaga *et al.* 2010) also comprised the investigations on biomass production under silvograzing. On this topic, Herrera *et al.* (2008) reported the spatial distribution of *Atta insularis* in leucaena systems.

Grassland management elements, such as stocking rate and number of paddocks, were pioneers in the productive results of animals in silvopastoral systems with leucaena (Castillo *et al.* 1996 and Ruiz *et al.* 1995). Bovine fattening and the free or restricted access of the animals to the protein bank with leucaena were studied (Castillo *et al.* 1989 and 1993). The tree utilization in 100 % of the area was considered, as well as its effect on the performance of male bovines (Castillo *et al.* 2000). In addition, the economical analysis of fattening alternatives with silvopastoral systems (Cino *et al.* 2006 and 2011) was performed giving continuity to these researches.

Supplementation with Saccharina in growing females under silvograzing with leucaena starts in an isolated and precise way (Zarragoitía *et al.* 1992). Mejías *et al.* (2003 and 2004) continued the studies of the rearing systems of the growing female using this legume.

Regarding milk production, first experiments were linked with the study of management for controlling the consumption of the *L. leucocephala* legume (Jordán *et al.* 1989). Later, they dealt with pre-partum feeding with non-irrigated leucaena and ferti-irrigated guinea grass Likoni (Jordán *et al.* 1994). The performance of the dairy cow in protein bank with leucaena during the dry season (Jordán *et al.* 1995) was also studied as part of the integral work carried out with this plant at the Institute of Animal Science.

SEASONAL LEGUMES

During the first years after the creation of the Institute, and in a punctual way, work was only carried out with peanut (Herrera *et al.* 1969) and bean (Sistachs 1970). There was a study published for each case and later research stopped.

At the beginning of the nineties, another of the subjects studied was the intercropping of seasonal legumes (*Glycine max*. and *Lablab purpureus*) during the establishment of tropical grasses (*Cynodon nlemfuensis*, *Megathirsus maximum* and *Pennisetum purpureum*). With the experimentation on this field it was demonstrated that this practice did not influence on the establishment of these plants and contributed to decrease the costs of this labor. In these trials it was possible to define the sowing dosage and the times for intercropping (Sistachs and Curbelo 1992, Ruiz *et al.* 1992b and Sistachs *et al.* 1992).

Studies developed with seasonal legumes having a multidisciplinary approach require to be mentioned. In them, the departments involved were: Pastures and Forages and Management and Monogastric production. In that occasion, investigations were directed to poultry production and, to a lesser extent, to the pig species. Among the species most studied were soybean (*Glycine max*.), *Lablab purpureus*, *Canavalia ensiformis*, *Stizolobium aterrimum* and *Vigna unguiculata*. Much attention was given to the latter.

The agronomic characterization and the comparative studies of biomass production for obtaining integral diets from vigna (Díaz *et al.* 2000 and 2001b) indicated

the potential of this plant for animal feeding. These studies included the harvesting time (Padilla *et al.* 2001b) for the legumes *C. ensiformis*, pigeon pea and *L. purpureus* and the influence of the sowing season on the bromatological characteristics of *C. ensiformis*, *L. purpureus*, *S. aterrimum* and soybean (Díaz *et al.* 2002a and 2003). Similarly, the nutritional indicators of vigna grain of grouped (Díaz *et al.* 2001b) and non-grouped (Díaz *et al.* 2002b) maturity were studied.

The bromatological characterization, with special emphasis on the protein percentages for obtaining foliar protein concentrates (FPC), initiated the studies on seasonal legumes (Díaz *et al.* 1997). Species assessed were *Canavalia ensiformis* (Díaz *et al.* 1998), *Lablab purpureus* (Díaz *et al.* 1998a), *Glycine max*. (Díaz *et al.* 1999b) and *Stizolobium aterrimum* (Díaz *et al.* 2000).

Research with animals started with the study of the protein quality of meals from raw beans of these legumes supplied to growing rats (Aguirre *et al.* 1998, 1999 and 2002). This topic motivated the physicochemical characterization of the fibrous fraction of foliage meals from vigna varieties (Savón *et al.* 2000, 2004 and 2007) and the studies of total polyphenols and condensed tannins (Scull and Savón 2003). Assays on apparent protein and energy digestibility were conducted in broilers consuming foliage meals of *Stizolobium deeringiana* (Martínez *et al.* 2007) and the morphometric indicators of the gastrointestinal tract and its accessory organs were evaluated with the inclusion of *Lablab purpureus* in their feeding (Martínez *et al.* 2008). Rodríguez *et al.* (2012) studied the microbial physiological groups and the fermentative indicators of broiler cecum fed *Stizolobium aterrimum* forage meal.

Lon-Wo *et al.* (1998) studied the utilization of these protein sources as an alternative for poultry feeding. Castro *et al.* (2002) enhanced them for growing pigs. The possibility of using sacchacanavalia in broilers (Valdivié and Elías 2006) demonstrated the usefulness of the solid state fermentation of sugar cane in combination with canavalia. Cino *et al.* (1999) evaluated the meals from raw beans of seasonal legumes and their potential use in poultry feeding. Lon-Wo *et al.* (2000) carried out the biological and economical evaluation of vigna meals in isoprotein diets for broilers.

A new approach on the use of seasonal legumes for monogastric animal feeding began with studies on vigna and *L. purpureus* beansprouts (Díaz *et al.* 2004, 2007 and 2011).

OTHER RESULTS

Studies developed by a group of scientists of the Institute of Animal Science in the above mentioned disciplines allowed the preparation and successful defense of various Master theses (Mejías 2004 and Díaz 2004) and Doctor in Science thesis (Zambrana 1973, Sistachs 1982, Monzote 1982, López 1982, Ruiz 1982, Pereiro 1985, Marrero 1989, Díaz 2000, La O 2001, Valenciaga 2003, Alonso 2004, Lok 2005, Mejías 2008, Díaz 2008, Martínez 2010 and Iraola 2013). These investigations propitiated the structure of a specific approach for the use and exploitation of these plants. In addition, as results of the work realized during the analyzed period, six awards were obtained from the Academy of Sciences of Cuba and two from the Ministry of Higher Education and the Ministry of Agriculture of Cuba, respectively. To these added the special FAO prize.

GENERAL CONSIDERATIONS

It is concluded that studies with creeping and shrub legumes allowed the development of integral technologies for the species *Neonotonia wightii*, *Leucaena leucocephalala* and the associations of multiple creeping legume mixtures with grasses. These investigations included the agricultural technique for its satisfactory establishment, digestive physiology, management for prolonging the productive life and the increase of their biomass production, feeding, supplementation and animal production in different bovine categories. Work put into practice with this plant family contributed a technology for biomass production of seasonal legumes for monogastric animal feeding.

Further studies are suggested on knowledge areas which during this stage, although considered in a punctual way, did not contribute decisively to the technologies developed. With systematic studies, these areas could complement the knowledge for the best use of these plants in animal production systems. In that regard could be cited studies on water use, biological fixation, fertilization, growth, grazing and weeds, including the evaluation of higher number of species.

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