Instituto de Ciencia Animal: fifty years of experience in the evaluation of grasses with economical importance for animal husbandry

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This study deals with the main results of the evaluation of grasses in the Instituto de Ciencia Animal from 1965 to 2014. Evaluations took into consideration aspects related to species and varieties, soil preparation, sown and establishment, intercropping, rehabilitation, nutrition, production of biomass and seeds, plagues and their control, physiological aspects, chemical composition and quality. In addition, the study refers to the effect of these grasses on biomass production and some guidelines are suggested for further researches.

Key words: grasses, evaluation

INTRODUCTION

Plants are living beings that synthesize every chemical substance they need for growing, developing and reproducing, using simple elements like carbon dioxide, water and light. This gives them the ability of establishing and surviving to different climate and soil conditions, among other factors.

Humans, at the beginnings, used plants for feeding, as a mean of protection, construction and as medicine. As they developed, they learned to sow and protect them. Plants were also companions for journeys, which favored their introduction to other territories. Potato, coffee, maize, wheat and some others are examples of it.

Nowadays, the constant growing of world population demands large amounts of plant origin feed. Domestic animals need plants of great economical importance for their nutrition that later transform into animal protein of high biological value for humans. In this context, it is necessary to develop studies on evaluation, selection and introduction of species, which will be based on researches on native flora, prospection and introduction of plants from other regions, with superior characteristics to those traditionally used. For countries that base their cattle feeding on grasses and forages, these researches have a special importance.

The objective of this review is to gather the main results obtained after fifty years in the Instituto de Ciencia Animal, regarding the evaluation of grasses with great economical importance for cattle rearing. These results have been constantly published in the Cuban Journal of Agricultural Science.

SPECIES AND VARIETIES

Since the foundation of the Instituto de Ciencia Animal in 1965, studies on evaluation of species and varieties started. The first results were published in 1967. At the beginings, researches were dedicated to sorghum (Berra and Preston 1967) and its hybrids (Tomeu and Meir 1969), as well as to maize (Casamayor 1968). The objective of these studies was to find the species that will be the most productive and the best adapted to Cuban tropical conditions. Later, these researches rapidly moved to those related to grasses.

The reasons of this performance were that grasses and forages are the nutritional basis for cattle because they can be sown during every season of the year. In addition, their use is biological and economically viable because ruminants have the ability of using these fiber feeds. Grasses and forages contributed to the conservation and improvement of the environment. Their proper use produces high yields of good quality and do not compete as food source with other species.

Pérez Infante (1970) studied the yield of the most spread eight grasses in Cuba at that time [*Digitaria decumbens* (Pangola), *Brachiaria mutica* (Paraná), *Hyparrhenia rufa* (Faragua), *Panicum maximum* (Guinea), *Andropogon annulatus* (Pitilla), *Andropogon pertusus* (Camagüeyana), *Andropogon caricosus* (Jiribilla) and *Paspalum notatum* (Tejana)], and established that natural species Pitilla, Camagüeyana, Jiribilla and Tejana did not surpassed the yield of the introduced ones. This study is considered as classic in national literature.

Panicum genus was widely studied. Monzote *et al.* (1976) evaluated 13 varieties of *P. maximum*. García *et al.* (2008, 2009) evaluated Mombaza variety and Fortes *et al.* (2014) assessed three varieties (Likoni, Mombaza and Tanzania). Results evidenced the differences among plants, their ecological plasticity, and potentialities they offer due to their high yields, aggressiveness and persistence, among other factor.

One of the characteristics of grasses is their seasonal biomass production because, during the dry period, they only reach 30% of their annual yield, which is determined by low temperatures, solar radiation, day duration and precipitations of this period. Therefore, experiments were performed to determine the capacity of production and use of species from temperate climate. Introduced varieties from Poland (Sistachs *et al.* 1979) and Germany (Ramos *et al.* 1995) were evaluated, which included Festuca, Dactylis, Phleum, Lolium and Avena genus.

Results showed the possibility of obtaining up to 7 t DM/ha of high quality (high percentage of protein and digestibility) during the dry period. However, this strategy was not developed due to the need of inputs (seeds, fertilization and irrigation), short exploitation period, competence with other species, high production cost, species that neither flowered nor produced seeds and the necessity of importing seeds of high cost.

Other alternatives were explored for producing forage, like *Amaranthus cruentus* (Crespo *et al.* 1988) and *Chenopodium quinoa* Willd (Ramos and Cruz 1998). However, their use was not feasible because they were sensitive to plagues. Besides, pesticides and other necessary inputs implied high production costs.

Pennisetum was another researched genus. The first studied species were Napier (Crespo and Guzmán 1973) and king grass (Ayala *et al.* 1983), which showed high yields and good quality. This caused that the 85 % of Cuban forage areas, during the 80´s of last century, were occupied by the second variety. However, the entire area had the same genetic pattern and it was necessary to increase the gen bank of this genus.

Martínez *et al.* (1988) used *in vitro* tissue culture and obtained several clones that surpassed their progenitor (king grass). Their differences were identified using electrophoresis of several iso-enzymatic systems (Cruz *et al.* 1993) and morphological describers (Febles *et al.* 2007). Out of these clones, two were selected. One of them had characteristics for grazing (Cuba CT-115), determined by its height, high leaf content, low flowering and high regrowth ability, and the other was appropriate for forage production (Cuba CT-169), due to its height and yield, and their long and wide leaves. In both cases, the chemical composition did not decreased rapidly with the age of re-growth (Martínez *et al.* 1994 and Herrera *et al.* 2014).

Herrera *et al.* (2012) evaluated another group of clones obtained from *in vitro* tissues culture and found marked differences in yield and leaf proportion, regarding their progenitor (Cuba CT-115). Low or null flowering in some of these clones was a favorable element. These differences were more marked when they were fertilized with nitrogen (Crespo y Álvarez 2014).

A part of the soils destined to cattle rearing, receives a process of salinization, while dry periods have more intensity and duration. This determined the obtaining of new clones of Pennisetum by Herrera *et al.* (2003), with tolerance to dryness and salinity. Those are in the evaluation stage, with promising results.

Another way for obtaining new varieties of *P. purpureum* was the irradiation of the agamic seed with gamma rays, from a source of ^{60}Co. The first stage consisted on the obtaining of radio-sensitivity curves (Cruz *et al.* 1991) that allowed to establish the way of irradiating in order to obtain mutants.

After evaluating the mutants, Herrera *et al.* (1993, 1994) stated that Cuba MF-1 and Cuba MF-2 surpassed forage production of its progenitor (king grass) in 10 and 17 %, respectively, when they were used without irrigation during dry season, and were fertilized with 180 kg N/ha during the rainy period. Besides, mutants had lower depopulation, higher amount of leaves and acceptable chemical composition.

Knowing native species of a determined geographic area is another important element in the search of varieties with economical importance for animal feeding. Álvarez *et al.* (2012a) made the prospection of plant species in two regions of Guantánamo province, Cuba, and established those of higher importance for their use in animal feeding.

The previously cited study allowed to introduce an important group of varieties of Digitaria, Cynodon, Panicum and Pennisetum genus into the social practice. However, nowadays, some of them are not used in a great extension, like Pangola and Bermudas. Nevertheless, star grass, Guinea Likoni and the new varieties of Pennisetum have a great acceptance.

SOWING, ESTABLISHMENT AND REHABILITATION

Sowing and establishing of grasses are the most expensive elements of grassland exploitation, which are mainly determined by expenses in soil preparation, seeds, and human resources, among others. Therefore, it is necessary to guarantee a proper sowing and establishment in order to obtain long lasting plantations of good quality.

Panicum maximum received a special attention. Factors like its establishment in natural grasses (Padilla *et al.* 1978), sowing methods (Padilla *et al.* 1979), times for spreading seeds and burning (Padilla *et al.* 1982), necessary population density (Padilla *et al.*1984), sowing date (Padilla *et al.* 1996) and sowing works (Padilla *et al.* 2009) were studied.

In *P. purpureum*, researches were also developed, related to sowing distance (Crespo and Guzmán 1973), planting depth and amount of buds (Ayala *et al.* 1983), parts of the stem and removal of the leaf blade (Ayala *et al.*1985), plantation methods (Padilla and Curbelo 2005), starting moment for soil preparation (Padilla *et al.* 2005)

and green manure application and growth stimulators (Padilla *et al.* 2005 and Herrera *et al.* 2007a).

Due to improper practices during sowing and establishment of grasses, among other factors, it is necessary to perform frequent rehabilitation works for extending the useful life of the grassland. Therefore, chemical and mechanical method were studied for rehabilitating *Digitaria decumbens* (Sistachs and León 1980), cultural labors and chemical fertilization (Padilla 2002), as well as methods and application of cattle manure (Crespo and Fraga 2005) on *P. maximum* Jacq and similar procedures on *P. purpureum* (Padilla *et al.* 2008).

Thus, the main elements for an optimal sowing and establishment of grass varieties were settled, as well as rehabilitation methods to minimize the use of chemical products.

INTERCROPPING

Intercropping is a common practice for managing grasses that helps to increase efficiency of land use and to obtain an additional harvest of high quality forage. However, it is important to know the moment to perform the intercropping, how to do it, and which crop to use.

Intercropping of *Helianthus annus* (Ruiz *et al.* 1989), sowing doses of *Hibiscus cannabinus* (Crespo *et al.* 1995) and of *Sorghum bicolor* and *Zea mays* (Padilla *et al.* 1998a, 2001) was studied at the moment or after (Ruiz *et al.* 1993, 1994) sowing *Cynodon nlemfuensis*. In the establishment of this grass, the influence of intercropping *Glycine max*, L*ablab purpureus*, *Amaranthus cruentus* (Sistachs and Curbelo 1992) and *Sorghum bicolor* (Padilla *et al.* 1998a) was researched, as well as sowing L*ablab purpureus* in the established grass (Ruiz *et al.*1992).

For continuing this research line, similar experiments were performed in two widely spread species in Cuba: *P. maximum* (Sistachs *et al.* 1990, 1991, 1992ab, 1993) and *P. purpureum* (Sistachs *et al.* 1990, 1995 y Padilla *et al.* 1998b).

These researches demonstrated the advantages of practicing intercropping of widely spread grasses in Cuba. However, nowadays, it is not used at a great scale maybe due to limitations of specific material resources.

FERTILIZATION

A vital element for producing grasses is the nutrient availability that allows their optimal growth and development. Several times, soil is not capable of meeting the nutrient needs of plants and it is necessary to use fertilization.

Pangola (*Digitaria decumbens*) was used in some assays for determining the effect of N fertilizer, with irrigation or not, on its yield (Wollner and Castillo 1968, Crespo *et al.* 1975 and Crespo 1984a, 1985). Application systems (Crespo 1972a), use method, foliar or not (Crespo 1972b y Crespo y Pérez 1974), were also investigated, as well as application moment (Crespo 1976) and economical efficiency of N fertilization (Cino *et al.* 1985).

A similar study was performed in species and varieties of Cynodon (Ramos and Curbelo 1978 and Ramos *et al.* 1992, 1993), Panicum (Crespo 1986), Pennisetum (Crespo and Curbelo 1992) and Brachiaria, Chloris and Andropogon (Crespo 1974). In addition, the combined effect of fertilizer and growth stimulators (Herrera *et al.*2008a) was researched.

Nitrogen is an essential nutrient and the response of grasses is not only determined by its availability in the soil but also by the amount and its relation with phosphorous and potassium. Obtained results evidenced this fact, after establishing the influence of NPK fertilization on Digitaria, Panicum and Cynodon (Medina *et al.* 1968, Crespo 1973 and Crespo *et al.* 1976).

Not only chemical fertilizers provide nutrients, organic sources also provide them. Crespo (1984b) studied composition, characteristics and application of cattle manure on grasses, combined to mineral fertilization (Crespo and Oduardo 1986), as well as the action of dungs and urine (Rodríguez and Crespo 1997). This author also analyzed the influence of mixing zeolite with mineral fertilizer (Crespo 1989). Rodríguez *et al.* (1994) studied the mixture of zeolite with excretions. All these researches were developed with the objective of improving the nutrient efficiency utilization.

Mineral fertilizers increases production costs, but their indiscriminate and continuous use turns them into contaminants of the environment and aquifer, among other aspects. Therefore, it is necessary to use other sources of nutrients, like organic ones, which provide nutritive elements and contribute to improve the physical and chemical properties of soil, decrease contamination, reduce costs and protect the environment.

FERTILIZATION, REGROWTH AGE AND COMBINED EFFECT

The relation between fertilization and regrowth age is an aspect of interest for evaluating grasses because it determines the efficiency level of the use of fertilizer and the age in which optimal economical, biological and

productive results are achieved.

Funes *et al.* (1980) studied the influence of cutting frequency on *Cynodon dactylon* cv. coastal, *P. purpureum* cv. selección 1, *Brachiaria ruziziensis*, *Cynodon nlemfuensis* cv. robusta azul, *Brachiaria mutica*, *P. maximum* and *Echinochloa polystanchya*. These authors established the best cut frequency for each grass and stated that the most frequent cuts had more negative effects on grassland longevity.

Researches were carried out in *C. nlemfuensis* for determining the combined effect of regrowth age and the dose of N fertilizer on yield (Ramos *et al.* 1980), on yield components and nitrogen use efficiency (Ramos *et al.* 1982), and on the extraction of soil nutrients (Ramos *et al.* 1987). The best combination of these two factors was determined, from the biomass point of view, without soil exhaustion.

A similar study was performed in *C. dactylon* cv. coast cross 1, after considering yields, nitrogen efficiency use and its residuality (Herrera *et al.* 1986 and Herrera and Hernández 1993), yield components (Herrera *et al.* 1987), extraction of soil nutrients (Herrera *et al.* 1988) and their morphological development (Herrera *et al.* 1991).

These results established that fertilization and regrowth age should be managed as a system and not as separated factors. It was considered as no reasonable to use doses of 400 kg N/ha/year and residuality of applied nitrogen did not exceed 12 weeks because they produced a mineral unbalance within the soil.

QUALITY, CHEMICAL COMPOSITION AND OTHER SUBSTANCES

Another important element for evaluating grasses is the knowledge of its quality and chemical composition because they are food sources for cattle. Besides, having other substances, like pigments that intervene in photosynthesis, contribute to improve management systems of grasses.

In *C. dactylon* cv. coast cross 1, the contribution of leaf and stem was studied, as well as that of fertilization and season on its chemical composition (Herrera 1979ab). There was also a research on the relation of N fertilizer and re-growth age on mineral composition (Herrera and Ramos 1980), hydrocarbons and nitrogen compounds (Herrera and Ramos 1982 and Herrera and Ramos 1983), digestibility (Herrera *et al.* 1985), vertical distribution of quality indicators (Herrera *et al.* 1984, 1986), amino acidic composition (Coto and Herrera 1989) and protein quality solubility (Coto *et al.*1990).

Assays related to chemical compositions were performed in *C. nlemfuensis*. Content of macro and micro-minerals (González *et al.* 1982, 1983, 1988 and González and Sánchez 1988), nitrogen fractions (Coto *et al.* 1989) and β carotenes (Estévez *et al.* 1988) were studied.

Another studied species was *P. purpureum*, researching on soluble and structural carbohydrates (Herrera *et al.* 1995), quality indicators (Herrera *et al.* 2014) and mineral composition (Herrera *et al.* 2008). Important results were obtained when the chemical composition of Cuba CT-115 (Valenciaga *et al.* 2009ab) and the monomeric composition of its lignin (Valenciaga *et al.* 2009c) were studied. These researches allowed to establish the relation between these component and digestibility. Under grazing conditions, using the technology of the biomass bank of this grass, its chemical composition was established (Fortes *et al.* 2012), as well as the movement of substances and water, before and after grazing (Herrera *et al.* 2002 and Fortes *et al.* 2004).

Original studies were carried out on the content of green pigments (chlorophyll a and chlorophyll b) and carotenoids in clones of king grass during their evaluation (Lauzán *et al.* 1989, 1990, 1991), mutants obtained by nuclear techniques and chemical mutagens (Herrera *et al.* 1996) in different varieties of Pennisetum (Herrera *et al.* 2009) and in CT-115 (Fortes *et al.* 2010).

These results established the influence of several factors on chemical composition and quality of different species, allowed to select the adequate moment for their use as food sources and facilitated de creation of rations that covered animal nutritional requirements.

SEEDS

P. maximum seed production was studied for optimizing sowings of this grass. Scarification and dormancy break (Febles and Padilla 1970) were researched, as well as the effect of varieties (Febles *et al.* 1996), season for cutting and fertilizer (Padilla and Febles 1980), N fertilizer and the moment for applying it (Febles *et al.* 1982), phosphorous and potassium fertilization (Febles *et al.* 1997a), and mineral nutrition and plant density (Febles *et al.* 1997b). In *P. purpureum* cv. Cuba CT-169, the influence of plantation distance and amount of fertilizer on the production on agamic seeds was also an assayed (Padilla *et al.* 2010).

PESTS

During the evaluation process, it is precise to consider the influence of pests because of the biological and economical damages they can cause during the exploitation of systems based on grasses.

During the first stage, there were studies with different chemical products for pest control of grain crops, like sorghum and maize (Ryder 1967ab). Later, researches were focused on grasses.

Barrientos (1981) studied residues of pesticides in *D. decumbens* Stent, different methods for controlling *Monecphora bicinta* fraterna Uhler in *C. nlemfuensis* and *C. dactylon* cv. Coast cross 1 (Barrientos 1983, 1985), as well as damages caused in the grasslands (Barrientos *et al.* 1988).

There were important researches on the effect of herbicides on seeds (Sistachs and León 1983) and the removal of seed coat and seed depth in germination of arvenses (Sistachs and León 1985).

Paspalum virgatum and *Sporobolus indicus* L.R.Br. are two widely spread weeds in the grasslands. Seed susceptibility of the first species to different herbicides was studied (Sistachs *et al.* 1982), as well as its chemical control and germination season (Sistachs y León 1986, 1987). In the second species, the studies were focused on its agamic reproduction (Febles *et al.* 2010), growth, development (Sardiñas *et al.* 2010) and phenological state (Padilla and Curbelo 2004). This favored the design of its control through methods of soil and plant preparation (Padilla *et al.* 2004), mechanical labors and strategic fertilization (Sardiñas *et al.* 2005), as well as the sowing of different grass varieties (Sardiñas *et al.* 2011).

Results allowed to decrease the use of chemical products and carry out the pest control through cultural labors and other practices that do not harm the environment.

MICROBIOLOGY

The influence of *Azospirillum sp.* on some indicators was researched, as well as on the yield of pastures (Hernández *et al.* 1990) like *P. maximum* (Hernández *et al.* 1993), *Chloris gayana* and *Brachiaria brizanta* (Hernández and Sarmientos1995), *Sorghum bicolor* and *Zea mays* (Hernández *et al.* 1994, 1997), and different types of soils (Hernández and Sarmientos 1997). Different inoculation methods were also studied (Hernández *et al.* 1996). However, the found responses were not consistent and studies stopped.

BIOMATHEMATICS

Researching pastures requires mathematical tools that allow obtaining precise, true, reliable and representative data of the studied population, among other factors.

Menchaca and Crespo (1975) and Torres (1981) determined the optimal size of plots, as well as the amount of replications (Torres 1984) and homogeneity index of the soil (Torres 1980) for experiments with grasses.

Another important aspect was sampling process. Torres and Martínez (1986) and Torres (1986) established the visual method and its variants (Torres and Jordán 1982) for estimating grass availability, as well as subjective sampling for this indicator (Torres *et al.* 1988). Later, Fortes *et al.* (2007) and Sardiñas *et al.* (2008) determined the sampling system for morpho-physiological studies of *P. purpureum* cv. Cuba CT-115 and biological characterization of *S. indicus*, respectively. Likewise, Herrera *et al.* (2013ab) quantified the variability of agronomical indicators of *P. purpureum* cv. Cuba CT-115 with sampling distance.

The use of multivariate techniques of information analysis allows to obtain more integral results and facilitates biological understanding. Torres *et al.* (1993ab) applied them in different stages of the process of evaluation and selection of grasses. Varela and Torres (2005) used them for characterizing clones of king grass. Febles *et al.* (2011), through these techniques, established the preponderance of edaphoclimatic factors on the production of grass seeds.

Mathematic modeling is another useful tool for the study of grass performance. Torres *et al.* (1999) apply it to the yield dynamics in *C. nlemfuensis*. Martínez *et al.* (2010) used it on biomass accumulation of *P. purpureum*, king grass, Cuba CT-169 and OM-22. Rodríguez *et al.* (2013ab) used it for estimating the dynamics of biomass production under different management conditions of king grass.

Therefore, it is evident the importance of mathematic tools for studying grasses. They allow to carry out precise experiments and obtain representative results of the sampled population. They also facilitate the explanation of biological processes and decrease material resources, without affecting the results and with time saving.

OTHER EVALUATED ASPECTS

In order to know the influence of growth promoterson grass production, the effect of the gibberellic acid on *C. dactylon*, *D. decumbens* Stent and *P. purpureum* (Herrera and Suárez 1975) was studied, as well as other promoters on the use of *P. purpureum* cv. Cuba CT-115 (Herrera *et al.* 2007). Results were encouraging, but the input values increased production costs.

Aspects related to development of radical system and water effect has not been studied enough. Nevertheless, Suárez and Hernández (1980) established the relation between aerial growth and roots in *P. maximum*. Meanwhile, Crespo and Lazo (2001) determined the biomass of roots in *C. nlemfuensis* and *P. maximum*, and Rodríguez *et al.* (2013c) did it in different grasslands from Mayabeque province, Cuba. Regarding the water balance, Suárez and Hernández (1977), and Suárez and Padilla (1978) quantified the effect of water deficit on biological indicators and during the establishment of *P. maximum*, respectively. Later, Álvarez *et al.* (2012b, 2013) reported on the influence of precipitations on grass management and on the combination of precipitations and temperatures on the production of clones of *P. purpureum*, respectively.

A less treated subject was the study of multiple sowing of grasses, with the objective of improving persistence, yield and grassland quality. Lazo *et al.* (1995, 1996, 1997) pointed out the advantages of a mixture of *P. maximum* and *C. dactylon* cv. 67.

Soil has not been paid enough attention. However, Crespo *et al.* (2006) studied the effect of different preparation labors of soils on their physical, chemical, and biological properties. Crespo and Otero (2011) carried out a similar study with *P. purpureum* cv. Cuba CT-115, planted in a commercial production enterprise. Lok *et al.* (2013) studied carbon storage in soil with the technology of biomass bank of *P. purpureum* cv. Cuba CT-115.

As it was evident, some knowledge areas has not been treated in the necessary extent, like in the case of radical systems, soil, growth promoters, carbon capture, and some other aspects. Therefore, it is necessary to intensify this type of research.

FINAL CONSIDERATIONS

This review used the concept of evaluation, in its widest sense, to cover the main aspects to be considered for knowing the characteristics of a grass variety and its response to different environmental and management factors. For its best presentation and understanding, the information was divided into sections, allowing a general view of the process. Integration of all information and its implementation makes possible the obtaining of sowing systems and exploitation of several grass species under Cuban conditions.

This way, technologies were obtained for sowing, establishment, intercropping, rehabilitation, biomass and seed production, quality and chemical composition, pest control, fertilization and their combined effect with regrowth age in species of economical importance for the country, like *C. dactylon*, *C. nlemfuensis*, *P. maximum* (currently *Megathyrsus maximus*) and *P. purpureum*, among others. It is debatable that for the development of this process, basic researches were necessary, which are related to the influence of microorganisms and photosynthetic pigments, among other factors, destined to support the studies and designs of technologies in exploitation.

The results of the use of organic fertilization and growth promoters were important, which allow the saving of mineral fertilizers, with the following improvement of soil properties, decrease of environmental contamination, exploitation of residues and increase of grassland longevity.

There were also important results from obtaining and evaluating clones of *P. purpureum* that lead to the development of technologies for forage production, as well as grazing on biomass banks.

Finally, results related to the application of mathematic tools are also very important. The optimal size of experimental plots was determined, as well as the number of replications and different sampling systems for different conditions, destined to obtain precise data that represent the sampled population. The application of systems of multivariate analysis allows a higher integrality and understanding of results. Besides, biological processes are accurately explained through the modeling process.

Although the evaluation process has advanced, new challenges appear and the steps should lead towards the evaluation of new grass varieties through the obtaining, prospection and introduction, climatic change adaptation and mitigation, soil salinization and degradation processes, tolerance and resistance to periods of intense droughts and prolonged rains, among other aspects. The final objective is the production of animal food, which has to be biologically and economically viable, to increase milk and meat production for meeting the growing demand of food for population. These challenges are not only for Cuba, but for many other countries.

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