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Bibliographic Review

Genetic characters of sunflower (*Helianthus annuus* L.) aiming the improvement for whole plant silage

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Abstract

Silage of quality is required by farmers for providing significant increases in productivity and maximizing the profitability of the productive system, being the sunflower crop (*Helianthus annuus* L.) an option for this purpose. The aim of this review was to discuss aspects about genetic characteristics linked to improvement of the sunflower for the production of whole plant silage. The genetic breeding of sunflower has got proportions after the discovery of cytoplasmic male sterility and of the restoration gene. The sunflower crop presents good forage potential and should be used in addition to corn silage. There are genetic resources for the breeding of the bromatological characteristics of the crop for forage production. As a rustic plant, the sunflower can be grown in regions or seasons which have risk of water shortages, generating income and enhancing the use of the land.

Keywords: Bromatological characteristics; heritability, hybrids; lines; cytoplasmic male sterility.

Caracteristicas genéticas do girassol (*Helianthus annuus* L.) visando melhoramento para silagem de planta inteira

Resumo

Silagens de qualidade são requeridas pelos agricultores por propiciar significativos incrementos na produtividade e maximizar a rentabilidade do sistema produtivo, sendo a cultura do girassol (*Helianthus annuus* L.) uma opção para este fim. O objetivo desta revisão foi abordar aspectos sobre características genéticas ligadas ao melhoramento do girassol para produção de silagem de planta inteira. O melhoramento genético do girassol ganhou proporções após a descoberta da macho-esterilidade citoplasmática e do gene de restauração. A cultura do girassol apresenta bom potencial forrageiro, devendo ser utilizada em complemento a silagem de milho. Há recursos genéticos para o melhoramento das características bromatológicas da cultura para a produção de forragem. Por ser uma planta rústica o girassol pode ser cultivado em regiões ou épocas que tem risco de déficit hídrico, gerando renda e potencializando o uso da terra.

Palavras chaves: características bromatológicas; herdabilidade; híbridos; linhagens; macha-esterilidade citoplasmática.

Caracteres genéticos de girasol (*Helianthus annuus* L.) con el fin de mejoramiento para ensilaje de planta entera

Resumen

La calidad del ensilaje son deseadas por los agricultores debido proporcionar un aumento significativo en la productividad y maximizar la rentabilidad del sistema productivo, siendo el cultivo de girasol (*Helianthus annuus* L.) una opción para este fin. El objetivo de esta revisión fue discutir aspectos sobre caracteres genéticos relacionados con el mejoramiento del girasol para la producción de ensilaje de planta entera. El mejoramiento genético del girasol creció en proporciones tras el descubrimiento de la macho esterilidad y del gen de la restauración. El cultivo de girasol presenta un buen potencial forrajero siendo importante como complemento de la ensilaje de maíz. Existen recursos genéticos para el mejoramiento

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de las características bromatológicas del cultivo para la producción de forraje. Siendo una planta rústica se pude cultivar el girasol en regiones o temporadas con déficit hídrico, generando ingresos y la mejora del uso de la tierra.

Palabras clave: características bromatológicas; heredabilidad; hibrido; macho esterilidad citoplasmatica.

Introduction

The use of silage of quality by the farmers from the South of Brazil has been providing significant increments in the yield of beef and dairy animals, maximizing the profitability of the productive system (NEUMANN et al., 2009a).

There are many forage species in the market, such as the poaceae and fabaceae, which can be used to make silage. In Brazil, the maize is taken as one of the best forage species due to its qualitative and quantitative characteristics (DEMINICIS et al., 2009). However, the maize crop presents high dependence of a water regime, what may oscillate the yield and quality of the silage obtained in different years.

According to RODRIGUES et al. (2001), the aim of the genetic breeding is in the search for a crop, which produces silage of good quality even under conditions of water deficit, maintaining a fermentative and bromatological stable quality pattern in the different years of cultivation. Among the agronomical characteristics which stand out in the sunflower crop (*Helianthus annuus* L.) are mentioned the greater tolerance to water stress in comparison to the maize, wide amplitude of cultivation under temperatures between 5° and 40° (NEUMANN et al., 2009b) and relatively short cycle (between 90 and 115 days), allowing the growth of sunflower during the off season and in succession to great crops, optimizing the agricultural area use (SILVA et al., 2007).

Among the chemical composition characteristics of the sunflower silage, these are presented with the highest values of brute protein, ethereal extract, mineral matter and lignin in the cell wall, in comparison to the maize silage (RODRIGUES et al., 2001).

Studies of sunflower genetic breeding with emphasis in the silage production are scarce, being one of the ways to contribute for the expansion of the sunflower cultivation in Brazil. According to OLIVEIRA et al. (2005), the programs of breeding in Brazil, aim the production of high oil content, early cycle, cultivars with low size, tolerance to abiotic and biotic factors and high yield of grains, not directed to animal feed.

This bibliographical review has as objective to approach aspects on the genetic characteristics connected to genetic breeding for the production of whole plants silage.

Genetic parameters allied to the breeding

The use of the hybridization method in the sunflower crop began at the same time of the maize crop, after the discovery of the cytoplasmic male sterility, although greater emphasis to the method application was given to the maize, in function of the difficulty of making crossings in the sunflower (SKORIC, 1992).

As stated by OLIVEIRA (2012), the cytoplasmic male sterility was identified by Leclercq, when he crossed the species *Helianthus petiolaris* Nutt with the *Helianthus annuus* L. thus indentifying the first source of cytoplasm male sterility (CMS). The studies with hybridization in sunflower managed to be introduced after the development of the fertility restorer gene, found in the United States by Kinman in 1972, since the process of hybridization is of hard achievement without the male sterility, due to the contamination and difficulty of directed crossings (OLIVEIRA, 2012).

With the obtaining of hybrids, there is the possibility of exploring the general combining ability (GCA) and the specific combining ability (SCA). The sunflower, maize crops and other the allogamous plants express their heterotic vigor when are crossed between divergent populations.

According to CASTIGLIONI et al. (1999) the GCA corresponds to the average behavior of the parent in hybrid crossings, where are evidenced the genes which confer additive effects, i. e. genes which contribute with a slight percentage in the effect of characteristic, for example, in yield. Now the SCA corresponds to the specific behavior, where the hybrid combinations can be superior or inferior to the average of crossings; the SCA explains the perfect combination between the linage A X B, for example, where in it are expressed the effects of dominance and epistasis, combinations which ensure great increase to the characteristic.

To BORÉM (1998) the knowledge of concepts

of heritability and phenotypic variability are important in the execution of a genetic breeding program for plants, where the heritability is the proportion transmitted to the progenies, of total variability of genotypes; and the phenotypic variability is expressed through the interaction between the genetic effects and the environment where the plant is subjected. The heritability in a general way can be explained as the ratio between the genotypic and phonotypic variance. In a more specific way, the heritability is defined as the ratio between additive and phonotypic variance.

To the breeding program achieve success, is necessary to know the characteristics of agronomic interest of the plant and the heritability of these, besides of having great genotypic diversity in the populations in study. One of the breeding strategies is the obtaining of hybrids, exploiting the heterosis, in the same as it is done in the maize crop.

Correlations and genetic heritability

When we think in breeding, is important to identify "natural markers", which can facilitate choosing the correct genotype, through the characteristics which directly or indirectly favor the aimed characteristic. In this thinking line, for the characteristic oil percentage in the sunflower achenes, where the desirable for the silage production is the decrease of the oil content, according a study done by AMORIM et al. (2008) the percentage of oil has negative genetic correlation with yield, weight of a thousand achenes and hectoliter weight, in values of r = -0.20, r = -0.42 and r = -0.18, respectively, what is good, because selecting genotypes with higher yield, is going to also decrease the contents of oil in the silage. These results confirm those found by HLANDNI et al. (2006), who observed negative correlation for the percentage of oil and weight of a thousand achenes r = -0.85 and/or yield r =-0.71.

According to DA SILVA et al. (2001) the component mass of capitulum shows positive correlations with biological yield of the plant (total mass of the plant), biological yield (mass per hectare) and total diameter of the capitulum, of r = 0.81, r = 0.86 and r = 1.00, respectively. Such fact allows inferring that with the selection of genotypes with greater capitulums, which is a characteristic of easy measurement, there is indirectly the selection of genotypes with greater mass production. These results corroborate with those found by Amorim et al. (2008), where the yield presented positive correlation with diameter of the capitulum r = 0.63 and with mass of a thousand achenes r = 0.55.

AMORIM et al. (2008) still states that there is no correlation between the plant cycle and yield, this is an important factor, because it can be selected premature genotypes, which is desired, due that normally the sunflower cultivation is done in the great crops off season period, without interfering in the cultivar or hybrid yield.

According to CAVALCANTE and SALIBA (2011) actually there is in the Brazilian market, cultivars which demonstrate good morphological attributes for the production of silage, an example is the hybrid M734 presenting itself in the form of silage with adequate fermentative characteristics and its conservation (5.5% of lactic acid, 1.5% of acetic acid, 0% of butyric acid and 7.3% of N-NH_3/NT).

The improvement is based in the selection of superior genotypes, in order that the selection is possible, it is necessary the generation of genetic variability, one of the ways to generate the variability is through the crossing and it is precisely through new genetic combinations that appear new cultivars (OLIVEIRA, 2012). When the genetic recombination is aimed it is important to know the heritability of the characteristic, since the characteristics which have a higher heritability are easier to carry out the transference from a plant to another as it is also the selection, because the environment has less effect on the expression of the characteristic (HARTWIG et al., 2007).

According to GHAFFARI et al. (2011) and ANDARKHOW et al. (2012) the diameter characteristics of the capitulum, plant cycle, yield and oil content, have average squares and low heritability, which indicates the importance of the non-additive genetic effects (effects of dominance) in the control of the characteristics, also verifying some cytoplasmic in the characteristics. GAVIRAGHI et al. (2010) also found low heritability for the characteristics linked to yield.

Hybridization method

One of the steps in the generation of hybrids is the obtaining of lines, which can be of easy generation, with self pollination, or more complicated through the backcrossing (MILLER and GULYA, 2006). To the same authors, the lines which presented in the genotype the fertility restorer gene (RHA) can

be obtained from successive auto pollinations of commercial hybrids of sunflower, male-fertile plants are selected from the segregating populations, the auto pollination is done to ensure that the plants have the S-RfRf genotype.

According to CARVALHO and TOLEDO (2008) for the achievement of lines with cytoplasmic male sterility (CMS-HA), the used method is the backcrossing, where it is used a line which have the cytoplasm type-S as recurrent parent, and a line, hybrid or variety which has in its kernel the alleles rfrf, regardless of whether the cytoplasm is normal (N) or S as donor, since the characteristics of cytoplasmic origin are only passed through the mother. In breeding programs, the lines possessing the cytoplasm S are obtained from other CMS-HA lines (MILLER and GULYA, 2006).

The crossing between the pure feminine CMS-HA line, with the genetic constitution S-rfrf, with other pure RHA line which is male-fertile, with genetic constitution S-RfRf or N-RfRF, will originate a fertile hybrid with the genotype S-Rfrf. The progeny carries the maternal cytoplasm, and 50% of its alleles are from maternal origin (rf) and 50% paternal (Rf) (CARVAHO and TOLEDO, 2008).

Bromatological quality of the sunflower silage

When the sunflower silage is compared to the maize or sorghum silage, we have superior contents of ethereal extracts (17.4% against 4.2% and 3.6%), minerals (3.5% against 2.5% and 1.7%) and brute protein (11.4% against 5.7% and 4.9%), respectively (MELLO et al., 2004).

In a study made by POSSENTI et al. (2005) the sunflower silage presented lesser content of dry weight than the maize silage, 22.0% against 34.6% respectively, according to the authors, the dry weight was lower due to the difficulty of identifying the correct point for the sunflower ensilage, but for the maize, the morphological characteristics facilitated the identification. Now, BITENCOURT JUNIOR et al. (2008) reported contents of 30.1% for dry weight in the sunflower silage.

The bromatological composition of the sunflower silage according to PEREIRA NETO et al. (2009), presents average values of dry weight of 23.87%, brute protein of 9.07%, ethereal extract of 13.34%, neutral detergent fiber of 46.10%, acid detergent acid of 36.02%, hemicelluloses of 10.40%, cellulose of 29.06%, lignin of 6.77%, calcium of 1.22% and phosphorus of 0.10%.

REZENDE et al. (2007) assessed the cutoff point for silage of six sunflower cultivars and the nutritional value of these, in this study the authors verified that when they did the cut of the plants at the 95 and 110 days after the sowing, the values of pH (4.31 against 5.24) and the content of dry weight (22.69% against 44.04%) of the silage presented inferior values when it was performed the early harvest. The values of pH found in the sunflower silage generally are higher than those in maize and sorghum, due to greater contents of brute protein and mineral matter, which influence in the buffering capacity of the mass and decrease the relation sugar/protein (EVANGELISTA and LIMA, 2001).

According to EVANGELISTA and LIMA (2001), the advance in the yield cycle of the sunflower crop for silage (95 to 110 days after the sowing) determined an increase in the contents of brute protein (11.20% against 12.43%) and neutral detergent fiber (54.65% against 55.03%), respectively, leading to a reduction of the digestibility "*in vitro*" of the dry matter (66.21% against 48.07%), this fact can be attributed to the late harvest, where there is higher participation of structural carbohydrates and interference of the lipid fraction in the plant (REZENDE et al., 2007).

The adequate harvest is a very important fact, since the dry weight content is related to the microbial activity, compression, production of effluents, buffering capacity, soluble sugars and yield (BITENCOURT JUNIOR et al., 2008). The proper stage to make the sunflower silage is the R9 (physiological maturation), because in this stage the plant presents dry weight content between 28 and 30%, the lower leaves are dry, the posterior region of the capitulum is yellow and the bracts became yellow with brown marks (FERREIRA NETO et al., 2009).

Agronomical characteristics

The achenes and silage mass yield is dependent of the technology used, including the fertilization, plants density, chosen hybrid, phytosanitary treatments, favorable weather and harvest season, mainly when it is destined to silage production.

MELLO et al. (2006), studying different sunflower hybrids and different seasons for sowing, noticed great oscillation between plants height, with plants varying from 1.15 to 1.79 m. The sowing during the month of October provided taller plants, independent of the hybrid, now for the sowing in November, the hybrids presented lower size, and in

December intermediate size.

SILVA et al. (2010), analyzing the reduction of spacing from 0.50 to 0.40 m found out that there was no difference for the plant height and culm diameter, this shows that the better distribution of seeds does not influence in these characteristics, since the population was of 60.00 plants per hectare both for 0.50 and 0.40 m. Now, for the yield, the spacing reduction provided an increase of 212 kg ha^{-1}.

The yield of the sunflower forage is good, achieving equal or superior yield in relation to the maize. OLIVEIRA et al. (2010), studying different species of forages (maize, sorghum-Sudan, forage sorghum and sunflower) verified that the greater productions of green weight were of the forage sorghum and of the sunflower, with 82 and 83.9 tons per hectare, even with the high amount of green weight, the dry weight was below the other forages, due to the stage of early harvest, with 19% of DW. On average, when the planting season was observed, it was verified that the sowing in December provided higher contents of DW in relation to October and November, and also had greater participation of the capitulum in the silage mass 61.1%, 47.3% and 58.1%, respectively (MELLO et al., 2006).

The plants population, cultivar and harvest season directly influenced in the DW yield, in sowings where the population varied from 30 to 88 thousand plants, it is noted that the DW yield oscillated from 5.32 to 11.08 tons per hectare (EVANGELISTA and LIMA, 2001).

The yield components such as the weight of a thousand achenes, capitulum diameter and number of achenes per capitulum are emphasized by authors as factors that stand out for the crop yield (VIJAYAKUMAR et al., 2003; CASTRO and FARIAS, 2005). SILVA et al. (2009) did not find statistical differences of the yield components, when studied the different hybrids of sunflower, with weight of a thousand achenes (59.7g), capitulum diameter (11.8 cm) and number of achenes per capitulum (380). MELLO et al. (2006) found significant differences between the hybrids and the sowing seasons, where the hybrid Rumbosol-91 presented a capitulum with greater diameter and the season in December the greater capitulum regardless of the hybrid.

Conclusions

The sunflower crop presents good forage potential and can be used as complement to the maize silage. There are actually, genetic resources for the breeding of the crop bromatological characteristics for the production of forage. For being a rustic plant, the sunflower presents a cultivation potential in regions or seasons which present moderated risk of water deficit, with possibility of yield increase and better use of the land.

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