Notas Científicas

Agronomic performance of quinoa selected in the Brazilian Savannah

Carlos Roberto Spehar[1] and Roberto Lorena de Barros Santos[2]

[1]Embrapa Cerrados, Caixa Postal 08223, CEP 73301-970 Planaltina, DF, Brazil. E-mail: spehar@cpac.embrapa.br [2]Esplanada dos Ministérios, Bloco D, Edifício Anexo A, Térreo, sala 1, CEP 70043-900 Brasília, DF, Brazil. E-mail: robertolorena@agricultura.gov.br

Abstract – Twenty six breeding lines, selected from individual plant progenies of hybrids among varieties Amarilla de Marangani, Blanca de Junín, Chewecca, Faro 4, Improved Baer, Kancolla, Real, and Salares-Roja, had their agronomic characters evaluated, in Planaltina, DF, Brazil (15°36'S and 47°12'W), 1,000 masl, in randomized complete blocks, on a Ferralsol, previously limed and fertilized. Grain yield was positively associated with plant height, inflorescence length and diameter, and plant cycle. Genetic gain can be attained by selection based in these characters for commercial production of quinoa in tropical regions.

Index terms: *Chenopodium quinoa*, breeding line, selection, yield, Cerrado.

Desempenho agronômico de quinoa selecionada no Cerrado brasileiro

Resumo – Vinte e seis linhagens, selecionadas em progênies de plantas individuais de híbridos entre as variedades Amarilla de Marangani, Blanca de Junín, Chewecca, Faro 4, Improved Baer, Kancolla, Real e Salares-Roja, foram avaliadas quanto ao desempenho agronômico, em Planaltina, DF, Brasil (15°36'S e 47°12'W), 1.000 m de altitude, em delineamento de blocos ao acaso, em um Latossolo Vermelho-Escuro, previamente corrigido e adubado. O rendimento foi associado positivamente com altura de plantas, comprimento e diâmetro da inflorescência e ciclo da planta. Ganho genético pode ser obtido na seleção baseada nessas características, para o cultivo comercial da quinoa em regiões tropicais.

Termos para indexação: *Chenopodium quinoa,* linhagem, seleção, rendimento, Cerrado.

Introduction of direct drilling in Brazilian Savannah has the opened way to diversification that mitigates negative effects of soybean monocropping by protecting the soil in the dry season and providing additional income to farmers (Spehar & Santos, 2002).

Quinoa (*Chenopodium quinoa* Willd.), Chenopodiaceae, is an alternative crop with favourable features for cropping systems in the savannah (Spehar, 1998). It is a major source of quality food that has been domesticated in Andean region for thousands of years (Spehar & Santos, 2002).

Quinoa is classified as a short day plant, although it is originated from a low-latitude and high-altitude environment. It also responds to changes in temperature, and the plant cycle results of these two factors conjugation. Early experimentation in the savannah indicates the high yield potential of locally selected lines (Spehar & Souza, 1993).

This work aimed at evaluating savannah selected genotypes from a broad-base hybridization in rainy and dry season sowings, and to determine adaptation characters for quinoa cultivation in low altitude and high temperature conditions of the tropics.

The germplasm was obtained from progenies grown in the dry season (winter), in Planaltina, DF, Brazil, located at 15°36'S and 47°12'W on an elevation of 1,000 masl. Individual plants with reduced branching and compact panicles were selected from hybrids among the varieties Amarilla de Marangani, Blanca de Junín, Chewecca, Faro 4, Improved Baer, Kancolla, Real and Salares-Roja, of Bolivian, Chilean and Peruvian origin (Carbone, 1986). These varieties represent a range of response to photoperiod, temperature and radiation, basead on their leaf appearance, onset of flowering, and reproductive phase (Bertero, 2001).

The experiments were conducted at Embrapa Cerrados (Savannah National Research Centre), Planaltina,

DF, Brazil. The soil is a Dark-Red Latosol, Oxisol (Typic Haplustox, fine, kaolinitic, isohyperthermic, USDA; Ferralsol, FAO), whose physical and chemical characteristics have already been reported (Santos el al., 2003).

Plant progeny selection was carried out during five growing cycles to obtain twenty six breeding lines, standardized for plant height (PH), days of maturity or growth period (GP), stem diameter (SD), plant colour and inflorescence type. They were tested in a randomized complete block design with three replications, during two consecutive dry seasons (winter), and one rainy season. Each plot consisted of seven rows, spaced 0.20 m apart, 3.5 m long. The harvest area consisted of five central rows, discarded 0.25 m at extremes. Before the start of each experiment, a fertilisation of 30 kg ha^{-1} nitrogen (N), 46 kg ha^{-1} phosphorus (P), and 60 kg ha^{-1} potassium (K) was used in the furrow. Nitrogen was also applied in band, 35 days after plant emergence, at the rate of 30 kg ha^{-1}.

Data were collected and statistically analyzed per individual relatively to days of flower differentiation, days to maturity (when 95% of the plants changed colour and were ripe), plant height, inflorescence type and size, stem diameter and colour, grain yield, total plant production and saponin (by the foam column method).

Mean values and correlation coefficients were calculated to assess the relationships among characters: plant cycle (PC), plant height (PH), grain yield (GY), total plant dry matter (PDM), inflorescence length (IL), diameter (ID) and type (IT), stem diameter (SD), stem colour (SC), foam column (FC), and harvest index (HI) proportion of grain to plant dry matter (g 100 g^{-1}) (Tables 1 to 4).

All accessions had a vegetative period of 19 to 23 days after emergence. At this point, flower differentiation took place at plant apex in all plots. Savannah temperatures – higher than those in the Andean region – is a possible explanation for the narrow range among genotypes related to the onset of flowering (Bertero, 2001).

Grain yield was higher in dry than in rainy season. Genotypes did not show correspondingly reduction for total plant dry matter. This is reflected in the lower harvest index (HI). The best performers for grain yield did not always coincide in the seasons, although there were some stable genotypes, such as the Q15. Maximum value, 2,600 kg ha^{-1}, obtained in dry season, was superior to average in the Andean altiplano, but inferior to that obtained in commercial crops (Spehar & Santos, 2002). High yields have also been achieved in temperate climates of the world with selected genotypes (Jacobsen et al., 1996).

Table 1. Grain yield (GY), inflorescence diameter (ID), inflorescence length (IL), plant height (PH), plant cycle (PC), and foam column (FC) for quinoa genotypes in dry season, 1995[(1)].

Genotype	GY (kg ha^{-1})	ID (cm)	IL (cm)	PH (cm)	PC (days)	FC (mm)
Q14	2,558a	40	26	106	115	6.7
Q6	2,296ab	36	24	71	116	6.3
Q4	2,223abc	32	22	86	95	7.5
Q5	2,047abc	34	26	71	110	6.1
Q22	2,033abc	29	19	88	86	6.3
Q9	2,007abc	22	16	73	115	6.9
Q11	1,867abc	30	18	71	86	7.7
Q1	1,783abc	29	23	73	121	7.3
Q3	1,747abc	25	22	70	120	6.3
Q17	1,747abc	18	15	88	119	6.3
Q15	1,743abc	36	21	79	126	8.3
Q18	1,731abc	32	21	89	91	8.0
Q10	1,684abc	24	20	70	95	6.0
Q7	1,648abc	27	23	76	116	5.5
Q20	1,643abc	22	20	71	85	8.9
Q25	1,623abc	28	16	71	91	6.1
Q16	1,557abc	22	20	71	96	7.5
Q8	1,523abc	28	24	68	95	5.1
Q21	1,515abc	30	25	61	85	9.2
Q13	1,365abc	27	16	63	87	7.1
Q19	1,280bc	29	19	54	94	7.2
Q12	1,248bc	26	15	56	84	8.7
Q23	1,157bc	35	19	61	86	9.8
Q26	1,146bc	28	18	78	95	5.3
Q24	1,054bc	21	18	56	114	6.4
Q2	1,024c	21	11	40	80	7.9
Mean	1,664	28	20	72	100	7.1

[(1)]Means followed by the same letter do not differ at 5% probability by the Tukey test.

Table 2. Grain yield (GY), plant dry matter (PDM), harvest index (HI), plant cycle (PC) and plant height (PH) for quinoa genotypes in dry season, 1996[(1)].

Genotype	GY (kg ha^{-1})	PDM (kg ha^{-1})	HI (g 100 g^{-1})	PC (days)	PH (cm)
Q2	2,351a	4,259def	55	110	95
Q15	2,056b	6,037ab	34	141	175
Q5	1,818c	6,360a	28	129	148
Q26	1,665cd	5,434c	31	119	173
Q14	1,516de	5,721bc	26	132	150
Q12	1,475e	4,396de	33	116	128
Q16	1,434e	5,604bc	25	125	158
Q9	1,431e	4,047ef	35	133	132
Q4	1,415e	4,602d	31	127	165
Q20	1,374e	3,831f	36	118	135
Q18	1,146f	4,206def	27	123	141
Q23	1,144f	3,102g	37	112	123
Q8	1,121f	4,283def	27	126	137
Q21	1,121f	3,150g	36	127	140
Q25	1,022fg	2,377h	43	125	113
Q13	998fg	324g	31	121	123
Q10	950g	325g	29	129	133
Mean	1,414	4,348	33	124	139

[(1)]Means followed by the same letter in the column do not differ at 5% probability by the Tukey test.

Table 3. Grain yield (GY), plant dry matter (PDM), harvest index (HI), inflorescence length (IL), inflorescence diameter (ID), stem diameter (SD), plant cycle (PC), and plant height (PH) for quinoa genotypes in rainy season, 1995(1).

Genotype	GY (kg ha^{-1})	PDM (kg ha^{-1})	HI (g 100 g^{-1})	IL (cm)	ID (mm)	SD (mm)	PC (days)	PH (cm)
Q15	1,735a	5,582abc	31	62	92	7.6	118	152
Q1	1,311ab	5,905a	22	44	59	5.3	102	105
Q18	1,225abc	5,884a	20	46	51	5.8	103	120
Q26	1,171abc	5,437abc	22	48	88	5.8	101	93
Q13	1,169abc	4,985abc	22	47	66	5.2	95	75
Q11	1,136abc	4,888abc	22	40	60	4.7	100	67
Q20	1,126abc	5,445abc	21	43	66	4.7	95	87
Q8	1,123abc	5,289abc	20	41	55	5.2	102	77
Q10	1,004bcd	5,937a	17	46	59	5.3	101	102
Q24	858bcde	5,763ab	15	43	83	4.8	103	101
Q25	802bcde	5,185abc	15	31	62	4.8	98	85
Q12	664cde	5,132abc	14	36	38	5.3	95	90
Q2	454de	4,578bc	10	32	41	4.7	92	62
Q23	273e	4,455c	6	36	23	4.7	95	69
Mean	984	5,001	20	40	59	4.9	100	87

(1)Means followed by the same letter in the column do not differ at 5% probability by the Tukey test.

Table 4. Correlation coefficients for plant cycle (PC), plant height (PH), inflorescence length (IL), diameter (ID) and type (IT), stem colour (SC), grain yield (GY), plant dry matter (PDM), harvest index (HI) and stem diameter (SD).

Variable	PH	IL	ID	IT	GY	PDM	SD	HI
Dry season, 1995								
PC	0.314*	0.367*	0.198		0.372*			
PH		0.534*	0.587*		0.757*			
IL			0.639*	0.033	0.592*			
ID				0.063	0.524*			
IT					0.036			
SC					0.015			
Dry season, 1996								
PC	0.514*				0.228	0.397*		0.657*
PH					0.688*	0.731*		0.604*
PDM								0.401*
GY						0.845*		0.406*
Rainy season, 1995								
PC	0.837*	0.608*	0.548*		0.747*	0.489*	0.715*	0.715*
PH		0.649*	0.440*		0.691*	0.629*	0.757*	0.636*
IL			0.530*		0.700*	0.559*	0.760*	0.666*
ID				0.079	0.571*	0.533*	0.461*	0.536*
SC				0.124	-0.051			-0.118
GY								0.999*
SD					0.616*	0.407*		0.604*
PDM					0.633*			0.489*
IT					0.308			0.406*

*Significant at 5% probability.

Plant cycle was longer in the second dry season experiment than in the previous one, but in both it was shorter than that observed in the Andes and Europe (Jacobsen et al., 1996; Bertero, 2001). Variation in days to maturity was found to be similar among quinoa genotypes, independently of sowing dates.

Plants were considerably higher in the two sowings than in the Andean region, where quinoa grows for a long period under the effect of low temperatures. Number of days from sowing to maturity was consistently different among the genotypes for the two sowing dates.

Grain yield was positively associated with plant height, length and diameter of inflorescence, and plant cycle. Selection for lateness has resulted in more productive genotypes, similarly to yield obtained in high latitude (Jacobsen et al., 1996).

Positive association among dry matter production, plant height and grain yield was expected; late maturity genotypes grew taller than the ones that matured early, being superior in other yield components. There are exceptions for harvest index, i.e., low values for late and high values for early maturity genotypes, which shows the possibility to develop quinoa for high grain and biomass productions to suit farming systems.

Inflorescence length and diameter were positively associated with grain yield, which indicates that selection by these characters may result in more productive genotypes. Positive correlation between plant height and inflorescence length suggests that high grain yield can be attained by selecting for stem/inflorescence ratio.

Stem diameter was also positively correlated with grain yield and biomass production; this is confirmed by field observations indicating that, under low population, plants increase their stem diameter and branching, and compensate for grain yield.

Additional studies are needed to improve crop performance, such as: selection for tolerance to high aluminium-low calcium in the low profile of soils and drought; relay sowing for moisture and time economy; effect of biomass and crop residue on soil protection and cropping sequences; definition of crop husbandry for high grain and forage production (Spehar, 1998; Spehar & Santos, 2002).

The agronomic performances shown by these genotypes are indicative of the potential for crop improvement, confirmed in more recent work (Spehar & Santos, 2002). It is expected by enlarging genetic variability that new cultivars will be acquired to suit production systems and extend commercial cultivation of quinoa in the tropics.

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References

BERTERO, H.D. Effects of photoperiod, temperature and radiation on the rate of leaf appearance in quinoa (*Chenopodium quinoa* Willd.) under field conditions. **Annals of Botany**, v.87, p.495-502, 2001.

CARBONE, J.J.M.R. **Adaptation of the Andean grain crop quinoa for cultivation in Britain**. 1986. 338p. Thesis (Ph.D.) - University of Cambridge, Cambridge, UK.

JACOBSEN, S.-E.; HILL, J.; STOLEN, O. Stability of quantitative traits in quinoa (*Chenopodium quinoa*). **Theoretical and Applied Genetics**, v.93, p.110-116, 1996.

SANTOS, R.L. de B.; SPEHAR, C.R.; VIVALDI, L. Quinoa (*Chenopodium quinoa*) reaction to herbicide residue in a Brazilian Savannah soil. **Pesquisa Agropecuária Brasileira**, v.38, p.771-776, 2003.

SPEHAR, C.R. Production systems in the savannas of Brazil: key factors to sustainability. In: LAL, R. (Ed.). **Soil quality and agricultural sustainability**. Chelsea: Ann Arbor Press, 1998. p.301-318.

SPEHAR, C.R.; SANTOS, R.L. de B. Quinoa BRS. Piabiru: alternativa para diversificar os sistemas de produção de grãos. **Pesquisa Agropecuária Brasileira**, v.37, p.889-893, 2002.

SPEHAR, C.R.; SOUZA, P.I. de M. de. Adaptação da quinoa (*Chenopodium quinoa* Willd.) ao cultivo nos cerrados do Planalto Central: resultados preliminares. **Pesquisa Agropecuária Brasileira**, v.28, p.635-639, 1993.

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