Spatial distribution of sunflower plants and their influence on yield in an environment of high variability

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ABSTRACT

- The spatial non-uniformity can be defined as the change in the spatial array of plants within the same seeding line. This uneven distribution can be produced by deficient seeders or by seeds of bad quality. For crops that are planted in rows, yield is affected by the spatial distribution within and between the row and plant population. The yield of a uniform crop is significantly higher than that of a patchy crop. The diameter of sunflower capitulum decreased with lower distance between plants. Yield reductions can vary between 35% and 62% in environments with low rainfalls, depending on the degree of non-uniformity, when the plant density is 5 pl m2. Such reduction was not detected in high yield potential environments. It is postulated that spatial non-uniformity will affect crop growth and yield to a larger degree in a high variable than in low variable environment, with high yields potential.
- The trial was conducted in the experimental field of the Faculty of Agronomy of the National University of La Pampa, Argentina. The hybrids Don Mario 233 and Paraíso 22 were sown at 70 cm between rows with theoretical distance of 24 cm between plants. The treatments (T) were Uniform (U) 5,5 pl.m^{-1} (plants grown to over 12 cm and less than 36cm), Fault (F) 3,9 pl.m^{-1} (plants grown to over 36 cm) and Duplications (D) 7 pl.m^{-1} (plants grown at less than 12 cm). The two factors were arranged in a split-plot design, where the hybrid factor (H) was assigned to the main plot and the treatment factor to the subplots. Non-uniformity was evaluated for plot, plant height (A), head diameter (DC), interception of radiation (IR %), leaf area per plant and leaf area index (LAI) and yield (R).
- The yields were was not different for H. Between treatments, U (3187 kg.ha^{-1}) was higher than F (2728 kg.ha^{-1}) and D (2446 kg.ha^{-1}) but between hybrids. In A, was not different for T, but Paraíso 22 (129 cm) was higher than DM 233 (120cm). DC, F (19,1 cm) was higher than U (17,2cm) and D (16,8 cm). AF and LAI differed significantly between treatments but not between the hybrids. AF for U (5211 cm^{-2}) was higher than F (4453 cm^{-2}) and D (4056 cm^{-2}). LAI U (2.97) was higher than F (2.51) and D (1.98). For every cm of standard deviation above or below the reference mean, yield losses were 78 kg ha^{-1} in F but 211 kg .ha^{-1} in D. We concluded that in a semiarid environment like the pampa steppe, losses of sunflower yields were better compensated at F than at D, where a competition effect affected plants production. The optimization of the density of plants is the first requirement for high yields, a condition that requires precise fulfilment of the performance of seeders.
- Adjusting the distribution uniformity of the sunflower crop plants improves yield in environments with low potential.

Keywords: uniformity - seeds - sunflower – yield.

INTRODUCTION

Sowing is the cultural work that pursues to obtain a population through the use of a machine that dosed leads and distributes the seed on the ground. The first requirement to achieve high yields, condition that requires precise compliance with the functions of the seed drill is to optimize the plants density (Kumar 1989, Albarrán Millan et al, 2006). Srivastava *et al* (1993) and Marrón, (2005) mention that there are features that must be always present in crops of precision and quality, these are: opening of the groove at a controlled depth, dosage of seed within the groove, in contact with the humidity, at a uniform depth in respect to the surface at uniform intervals, or an equidistant way between successive seeds, covering the furrow and squeezing soil against the seed.

The space non-uniformity can be defined as the variation in the equidistance between the plants of the same line and it is related to the behaviour of the dispenser and the quality of the seed to dosage. Delafosse (1986) mentions that for crops that are planted in rows, the yield is affected by the distribution of the spacing between plants and the population of plants per hectare.

When the plants stand is non-uniform, the over-density exerts an effect of competition and dominant and dominated, plants suffering a great abortion of flowers during flowering, causing a drop in yield.

A way of measuring the variability of the spacing between plants is through the standard deviation (DE). Studies for six years in Indiana (United States) on the spatial location (distribution uniformity) plant corn and its influence on yield, made it possible to conclude that for every cm of over 5, lost 62 kg ha^{-1} yield potential (Nielsen, 2001).

In 1971 and 1972 Remussi *et al*, (1974), with sparse plants they generated spatial variability, so that they stay at a different distance: uniform when there was a perfect equidistance between the plants that it was the treatment used as witness, patchy considering it as possible in planting field where the distance between plants ranged between 10, 20, or 30 cm, and non-uniform where the spacing between plants exceeded the 40 or 50 cm or were less than 5 cm, along the same line. The uniform crop yield was significantly higher, compared with little uniform and non-uniform. The greatest loss of plants occurred when they were less than 5 cm distance reaching 46% and 25% when the distance was 10 cm. The diameter of the capitulum noted the same trend, registering lower values when plants were very close and the biggest when plants were at a greater distance, due to a greater place to vegetate. Saumell *et al* (1974) mentioned that you achieved a greater diameter of the capitulum to reduce the number of plants per surface, attributed to a better and more adequate distribution of the plants of sunflower field. The diameter of the capitulum decreases with the increase in population, from 11 inches for populations of 7000 plants per acre, to 7 inches for populations of 25000 plants per acre Robinson *et al* (1982) and Oliverio, (1979) conclude that same final number of plants misallocating leads to reduction in yield. When the uniformity of plants in the line of sowing is good, there is a good response from the crop (Bragachini, 1984).

Wade et al, (1988) assessed the joint effect of density and uniformity of sowing on the crop yield in environments of low yield potential and observed reductions of between 35% and 62% depending on the degree of non-uniformity when the density was 5 pl m^{-2}. In addition to low densities yield drops with or without non-uniformity. Sparse crops the main cause of the fall of yield is the lack of plants and not its distribution. High densities compound the problem of the non-uniformity.

Trapani et al., (2000) did not observe reduced potential output in Argentina in non-uniformity sunflower crops planted in high density environments of high yield potential.

Maroni, (2000) quoted by Nardon, (2003) mentions that you can be considered acceptable a planting where 70% measurements of the distance between seeds or plants is located in a covered range between 25% above or below average. In the same vein Schrõdl, (1982) and Marquez, (1994) cited by Gil Carnasa, (1996) proposed that each seed located at a distance of 20% above or below the theoretical distance will produce a viable plant with no negative impact on yield.

The sunflower has a great capacity to heavily modify the individual behaviour of the plants with changes in density, because of sunflowers with lower density reach a good radiation interception during the critical period of generation of yield under conditions of good water supply (Andrade, 1995). The leaf area per plant is inversely related to the density of plants of the crop (Sadras and Hall 1998). Thus, cultivation of very different density reaches similar values of maximum LAI, while considering the leaf area per plant the value may double at low densities (Sadras *et al* 1989).

It is postulated that in an environment of high variability, the spatial non-uniformity affects the growth and yield of the crop.

MATERIALS AND METHODS

The trial was sown in the Faculty of Agronomy of the National University of La Pampa located at 36° 46' S and 64 ° 16' W, and 210 m above sea level, belonging to the geomorphology of the plain with limestone. The ground intended for the experiments is a Haplustol indoor with a sequence of Horizons A-AC - C1-C2Ca and a maximum effective depth to the layer of limestone by 1,50m.

The treatments evaluate were: uniform (U) (in 2 m 8 well distributed plants); Failures (F) (on 2 meters less than 8 plants and were more space that the theoretical distance), duplication and (D), (in two meters of groove over 8 plants and less spaced than the theoretical distance).

Don Mario 233 and Paraíso 22 hybrids have been used. Sowing took place on December 5, 2009 with a seed drill Super Walter of 10 drills 0,70m between rows, with a theoretical density of 4 plants per meter, in a split plot design, which was allocated to the main plot factor hybrid (H), treatments (T) and subplots U, F. and D. Each main plot was sown with 5 rows of each hybrid, fifty meters in length, with four replications.

To make the determinations were chosen in each main plot, 4 subplots 2 meters of groove of each treatment to evaluate.

The non-uniformity of the plots was determined using a theoretical distance reference of 25cm, and taking into account that any plant that is found at a time and mid-distance the reference (37, 5cm) was an F and which was less than once and a half the distance from reference (12,5cm) is a D (standard ISO 72561).

In each plot was measured: plant height (A), diameter of capitulum (DC), interception of radiation (IR), leaf area per plant (AF), leaf area index (LAI) and yield (R).

The interception of radiation was taken in vegetative state R 5.5 in the scale proposed by Schneiter and Miller (1981), between 11: 30-hour time 13: 30 in a fully clear day.

The capitulum are harvested manually and threshed with a static thresher.

Statistical analyses were performed with the InfoStat 2008 program.

RESULTS AND DISCUSSION

In all analyzed variables were not find no significant interaction between hybrids and treatments, so it was proceeded to review the main effects (H and T) for each variable (table 1).

No differences were found in the density of plants between H, but there were in the distribution of them. This difference is attributable to the dispenser and the calibration of the seed.

The difference in the A of plants was significant for the comparison between hybrids, due to the characteristics of each genotype. Differences were not significant in treatment, proving that both D and F do not generate difference in the A of the plants.

The variable DC showed significant difference between the hybrids; this is attributed to each genotype characteristics. F treatment threw the highest DC significant differences with U and D. This is because the sunflower find a greater free space without competition with other plants and it would develop a capitulum of greater size, coinciding with the statement made by Remussi *et al* (1974) Saumell *et al* (1974), Robinson *et al* (1982).

The AF per plant was greater in U than in D and is equal to F. The effect of D, with the reduction of the distance between plants in the planting row explains the lower individual AF plant.

The LAI was higher in U and lower in F. We may say that the density modified by F or D affects the LAI; in this case F treatment could not balance the lack of individuals with size of leaves in the plots. This coincides, in part with Sadras *et al* (1989), who found that plots of different density showed significantly different LAI.

The largest IR occurred in U, while the interception of radiation recorded in F was significantly lower, sunflower could not balance the lack of plants with size and quantity of leaves. In F, nevertheless plants had a very good size, the uneven distribution of them made they remain large areas without cover allowing the passage of sunlight decreasing radiation interception. For Andrade (1995) sparse crops reach a good radiation interception during the critical period of grain filling, but in our case this is not true due to the non-uniformity in the distribution of plants. Two hybrids of behave similarly in F and D.

Table 1. Means values of the analysed variables

H	**D** $Pl.m^{-2}$	**H cm**	**DC cm**	AF cm^2	LAI	IR %,	**R** $Kg.ha^{-1}$
Paraíso 22	5,64	129 a	18,38 a	4700	2,52	74,2	2822
DM 233	5,56	120 b	17,10 b	4580	2,46	73.0	2752

P value	NS	0,0308	0,0042	NS	NS	NS	NS
T							
U	5,50 b	128	17,28 b	5211 a	2,97 a	94.0 a	3187 a
F	3,90 c	126	19,14 a	4653 ab	2,51 b	71,8 b	2728 b
D	6,96 a	119	16,80 b	4056 b	1,98 c	55.0 c	2446 c
P value	<0,0001	NS	0,0001	0,0023	0,0004	0,0003	<0,0001

Letras distintas indican diferencias significativas (p<= 0,05) test de LSD de Fisher.

The effect of the non-uniformity produced decreases in yield coinciding with the provision, Remussi e*t al*, (1974), Oliverio (1979). Treating U with a proper distribution was the greatest yield, Bragachini, (1984). This is because the semi-arid area condition where the test was developed, make the effect of competition between plants more accentuated and this was manifested in the yield, in contrast to that found by Trapani et al, (2000) who did not obtain differences in yield on crops planted in the form non-uniform in environments of high potential. On the other hand the plots (F) where the plant had less competition, resources were not sufficient to compensate the loss of individuals. D treatment effect was more declined in yield than F.

In plots with F (table 2) seeds were located at a distance of 32 % above theoretical average, whereas the D were found in a 16 % below. In plots where the seeds are located in a 32% above the middle or a 16% below, affected the crop yield. This information coincides in part with the statement made by Schrõdl, (1982) and Marquez, (1994) who claim that seeds located at a distance of 20% above or below the theoretical distance will produce a viable plant with no negative effects on yield. If 70% of the measurements are in the range of 25% above or below the average of reference planting is considered acceptable Maroni (2000). In this case seed located 16% below the average of reference apparent loss in yield.

Table N° 2.- Plant spacing variability.

H	T	Means (cm)	DE for H	DE for T	CV for H	CV for T
DM 233	U	26,8	1,79	1,96	6,66	7,19
Paraíso 22	U	27,58	2,13		7,73	
DM 233	F	34,77	6,1	5,87	17,53	15,2
Paraíso 22	F	43,94	5,65		12,87	
DM 233	D	21,31	3.98	3,51	18,68	16,08
Paraíso 22	D	22,61	3,05		13,49	

Every centimetre of standard deviation above or below the average of reference losses in output that is generated with F are 78 kg ha^{-1}, on the other hand when there has been a doubling loss amounted to 211 kg ha^{-1} (table 3).

Table 3. Decrease in the yield per every centimetre of standard deviation above or below the average of reference.

	Non-uniformity (cm)		Yield (kg ha^{-1})				
T	DE	CV	DE	CV	Means	Yield difference	kg.ha^{-1} losses by cm's of DE
D	3,51	16	446,47	18,25	2446	741	211
F	5,87	15,2	299,25	10,17	2728	459	78
U	1,96	7,19	453,17	14,22	3187		

CONCLUSIONS.

The distribution of the plant affects yield in environments of high variability.

The effect of competition that occurs with duplication affects the two plants and these do not contribute to the yield.

Sunflower in environments of high variability compensates better for failures that duplication.

REFERENCES

Albarrán, Millan, M.; Torres Sandoval; M. Audelo Beneitez y J. Ochoa Bizarro. 2006 Comparación de dos sembradoras neumáticas con diferentes sistemas de dosificación de semilla. *En*: Actas de V Congreso Interamericano de Ingeniería Agrícola, Chillán, Chile. En soporte magnético. 11pp.

Andrade, F. 1995 Analysis of growth and yield of corm, sunflower and soybean growth at Balcarce, Argentian. Fiel Crops Res 41:1-12.

Bragachini, M. y S. Castellano. 1984 Ensayo comparativo de sembradoras neumáticas y mecánicas en el cultivo de girasol. Informe inédito. INTA. EEA Manfredi.

Delafosse, R.M. 1986. Máquinas sembradoras de grano grueso. Santiago, Chile: Oficina Regional de la FAO para América Latina y el Caribe. 48p.

Gil, E., y R, Carnasa.1996 Working quality of spacing drills effectos of sowing speed and type of seed. Paper 96A-023. Congreso de Ingeniería Agrícola. Madrid 1996. España. (AgEng. 96)

InfoStat 2008. *versión 2008.* Grupo InfoStat, FCA, Universidad Nacional de Córdoba. Primera Edición. Editorial Brujas Argentina

ISO 7256/2-1984 (E)

Kunar, A. 1989. Effect of sowing equipments on crop yield ander dryland conditions. Seeds and Faros 15 (3): 24-29.

Marron G., 2005. La sembradora: equipamiento y regulación para soja. En. Soja-Eficiencia de Cosecha y post cosecha-Propeco-INTA. 32:59.

Nardon, G., 2003. Siembra de Precisión: Modelización de la distancia entre semillas. Tesis de Maestría. Departamento de Mecanización Agraria Facultad de Ciencias Agrarias y Forestales Universidad Nacional de La Plata Bs. As.

Nielsen R.L. (Bob). 2001 Stand establishment variability in corm. Trials Purdue University, Agronomy Dept., W. Lafayette, AGRY-91-01:1-10.

Oliverio, G., 1979. Uniformidad de siembra en el cultivo de girasol. CREA 80:26-30.

Remussi C., Saumal H., y G.A. Vidal Aponte. 1974. Efectos de la Uniformidad de Siembra en Girasol. Acta Segunda Reunión Nacional de Girasol. 9, 10 y 11 de octubre Bs. As. Pp 22-28

Robinson. R. G., Ford. J. H., Lueschen. W. E., Rabas. D. L., Warnes. D. D., y J.V. Wiersma. 1982. Sunflower Plant Population, and lts Arrangement. Universidad de Minnesota. Extension Service, MR-2144.

Sadras, V. O. y A.J.Hall. 1988. Quantification of temperature, photoperiod and population effects on plant leaf area in sunflower crops. Field Crops Res. 18. 185-196.

Sadras, V. O.; A. J. Hall; N . Trápani and F. Vilella 1989. Dynamics of rooting and root length: leaf area relationships as affected by plant population in sunflower crop. Field Crops Res 22: 47- 45.

Saumell. H., Remussi. C., y G.A. Vidal Aponte. 1974. Efectos de la densidad de siembra en el girasol. Acta Segunda Reunión Nacional de Girasol. 9, 10 y 11 de octubre Bs. As. Pp 29-43.

Schneiter, A.A., y F.F. Miller . 1981. Description of sunflower growth stages. Crop Sci. 21: 901-903

Srivastava, A. K., Goering, C. E., y R.P. Rohrbach.1993 Engineering principles of agricultural machines. Ed.: American Society of Agricultural Engineers. 601 pp.

Trápani N, Lopez Pereira M, Sadras V, y A.J. Hall. 2003 Ciclo ontogénico, dinámica del desarrollo y generación del rendimiento y la calidad en girasol. Capítulo n° 10 Libro "Producción de granos bases funcionales para su manejo" Ed. FAUBA. 2003.

Wade, L. J., Norris, C. P., y P.A.Walsh. 1988. Effects of suboptimal plant density and non uniformity in plant spacing on grain yield of raingrown sunflower. Australian Journal of Experimental Agriculture. (28) 617 – 622.