# Yield components and grain yield in two Argentinian wheat *(Triticum aestivum* L.) cultivars differing in plant height under different nitrogen supply

Caldiz, D.O. and S.J. Sarandon

**SUMMARY**

The purpose of this work was to study the relationship between yield components and yield in two cultivars with traditional or Mexican germplasm, when grown under different nitrogen (N) supply during the crop cycle. Klein Toledo and La Paz INTA, a standard height and a semi-dwarf cultivar, respectively, were grown under high (H) and low (L) nitrogen supply, changed at maximum floret number stage. N shortage early during crop cycle severely reduced tiller and spikelet number and dry weight.plant$^{-1}$, this effect being greater for the semi-dwarf cultivar, where reductions of 34, 42 and 70% were registered for these variables. N shortage at maximum floret number stage reduced all the variables measured, except floret number, which seems to be less sensitive to environmental constraints than other variables. Reductions in the number of potential grain sites at this stage due to decrease in spikelet number was not modified by later applied N. Hence, at harvest, grain number.ear$^{-1}$ was markedly affected, but no differences between cultivars were registered.
In addition, it was demonstrated for both cultivars that N assimilation continues well after anthesis, probably due to a significant retention of root function. When high yields are the goal and when no other limitations exist, early N supply seems to be the key to achieve such results.

**Key words:** spikelet number, maximum floret number, potential grain sites, grain yield, wheat.

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**RESUMEN**

El objetivo de este trabajo fue estudiar las relaciones entre el rendimiento en grano y sus componentes en dos cultivares, uno de ellos con germoplasma tradicional y el otro mejicano, cuando éstos eran cultivados con distinta disponibilidad de N a lo largo del ciclo de cultivo. Klein Toledo y La Paz INTA, cultivares de altura standard y semi-enano, respectivamente, fueron cultivados bajo alta (H) y

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baja (L) disponibilidad de N, modificada al estadio de: número máximo de flores. La baja disponibilidad de N al inicio del ciclo de cultivo redujo severamente el número de macollos.planta$^{-1}$, el número de espiguillas.espiga$^{-1}$ y el peso seco.planta$^{-1}$ siendo este efecto mucho mayor en el cultivar semi-enano, donde se produjeron reducciones del 34, 42 y 70% para estos parámetros, respectivamente. Al estado de número máximo de flores la menor disponibilidad de N produjo reducciones en todos los parámetros evaluados, a excepción del número de flores.espiguilla$^{-1}$, que parece ser menos sensible a limitaciones de tipo ambiental que otros parámetros. Las reducciones en el número de sitios potenciales para formar grano (número de espiguillas.espiga$^{-1}$ x número de flores.espiguilla$^{-1}$), al estado de número máx mo de flores, debido a disminuciones en el número de espiguillas, no fueron modificadas por el posterior agregado de N. De allí que, a la cosecha, el número de granos.espiga$^{-1}$ haya sido marcadamente afectado, aunque no hubo diferencias entre los cultivares.
Por otra parte, también se demostró que, en ambos cultivares la asimilación de N continúa aun luego de antesis, probablemente por una mayor retención de la capacidad funcional de las raíces. Cuando el objetivo del cultivo es obtener altos rendimientos, y no existen otros factores capaces de limitar el mismo, la disponibilidad temprana de N es clave para lograr resultados favorables.

**Palabras clave:** número de espiguillas, número máximo de flores, sitios potenciales para formar grano, rendimiento, trigo.

*Daniel O. Caldiz. Instituto de Fisiología Vegetal, INFIVE, Departamento de Biología y Ecología, Facultad de Ciencias Agrarias y Forestales, UNLP. CC 327, 1900 La Plata. Santiago J. Sarandon. Área Cerealicultura, Departamento de Producción Vegetal, Facultad de Ciencias Agrarias y Forestales, UNLP. CC 31, 1900 La Plata, Argentina.*

## INTRODUCTION

In Argentina during the last decades the area cropped with wheat has stabilized at around 5 x $10^6$ ha (Klatt, 1986), while for the period 1976-1985 the average yield increase in two of the main wheat cropping areas, for both long and short cycle cultivars, was 92 kg.ha$^{-1}$.year$^{-1}$ (Nisi *et al.*, 1986). This increment is mainly attributed to the incorporation of semi-dwarf cultivars with Mexican germplasm (Nisi & Legasa, 1986) which are considered as high yielding (Dalrymple, 1986). Its introduction enhanced, in many cases, the inverse relationship between yield and grain protein percentage (Löffler *et al.*, 1985), as was also demonstrated by Sarandón & Caldíz (1990). In addition, it has been demonstrated by several authors, that yield improvements were achieved through increases in the harvest index (Austin *et al.*, 1980; Ledent & Stoy, 1988; Perry & D'Antuono, 1989; Slafer & Andrade, 1989; Slafer & Andrade, 1990) with no gain in biological yield. However, only recently, attention was paid to the development of yield components and their effects upon grain yield (Slafer & Andrade, 1993; Slafer & Miralles, 1993) in cultivars obtained in different eras. Nevertheless, it is well known that traits set early in morphogenesis may govern the whole plant design by triggering a series of reactions affecting organs formed later in the development process (Grafius, 1978). Genotype x environment interactions modify such traits and lack of certain resources can reduce the potential production achieved through these components. For example N shortage can severely reduce tiller, spikelet and floret number (Single, 1964; Beveridge *et al.*, 1965; Spiertz *et al.*, 1984), while an increase of N supply near the double ridge stage can increase spikelet number (Langer & Liew, 1973).

Based on these and other evidences (Caldiz & Sarandón, 1988), the hypothesis of this work is that high yielding cultivars are more sensitive to environmental constraints. Hence, in order to demonstrate this idea, the aim of this work was to study, under ample and reduced N supply, the response of a standard height and a semi-dwarf cultivar, on yield and its components.

## MATERIALS AND METHODS

Klein Toledo a standard height cultivar released in 1969 and La Paz INTA a semi-dwarf cultivar with Mexican germplasm, released in 1981, were used in this experiment due to their similar cycle length but different yielding ability. Seeds of each cultivar were sown on 31st July 1985 in containers of 0.028 $m^3$ (0.25 x 0.45 x 0.25 m depth) at a density equivalent to 300 $pl.m^{-2}$ (34 $pl.container^{-1}$). The containers were distributed in the field at enough distance to avoid shading effects due to differences in plant height. A plastic roof covered the containers to avoid rainfall. Average daily temperatures ranged from 10°C, at emergence, to 25°C at harvest time. The substrate was a mixture of sand and perlite (50:50). From emergence plants were irrigated with Hoagland and Arnon's (1950) nutrient solution, modified by the addition of urea at a rate of 200 $mg.l^{-1}$ (high nitrogen, H) and 40 $mg.l^{-1}$ (low nitrogen, L), as follows: HH: irrigation with solution H throughout the experiment; HL: irrigation with solution H till maximum floret number and afterwards solution L; LH: irrigation with solution L till maximum floret number and afterwards solution H; and LL: irrigation with solution L throughout the experiment. There were four replications per treatment with four containers per replication, each one used for the intermediate and final harvests. Treatments were divided at maximum floret number stage because previous work showed that, the maximum number of potential grain sites is achieved at that developmental stage (Caldiz & Sarandón, 1988). Apex developmental stages were registered by periodical observations on the main stem, with a stereocopic microscope (Bausch & Lomb ASZ45E) and classified according to the scale proposed by Moncur (1981) as: (1) terminal spikelet stage; (2) maximum floret number stage; (3) ten days after anthesis and (4) maturity.

Harvests of five plants per replication were done at stages (1) to (3). In each harvest total tiller number and fertile tiller $number.plant^{-1}$, spikelet $number.ear^{-1}$, ear length, dry $weight.plant^{-1}$ and maximum floret $number.spikelet^{-1}$ were recorded. At stage (4) all yield components were determined over 10 plants per replication, on the main stem.

Potential grain $sites.ear^{-1}$, at maximum floret number stage, was calculated by multiplying the values of maximum spikelet $number.ear^{-1}$ x maximum floret $number.spikelet^{-1}$. This value was compared with grain $number.ear^{-1}$, in the main stem, at the final harvest to establish the reduction in the number of potential grain sites.

Results were analyzed in a completely randomized design and mean differences determined by Tukey's test (P: 0.05).

## RESULTS AND DISCUSSION

Even when some variability coefficients were high (Table 1 to 3) for this kind of experiment, carried out under partially controlled conditions, the effect of the treatments were so important that significant differences were still found for the variables measured.

N shortage early during crop cycle severely reduced tiller $number.plant^{-1}$, spikelet $number.ear^{-1}$ and dry $weight.plant^{-1}$ (Table 1) in accordance with

**Table 1.** Tiller number per plant, spikelet number per ear in the main stem and total dry weight per plant at the terminal spikelet stage (1) for both cultivars, La Paz INTA (LP) and Klein Toledo (KT).

| Treatments | Tiller number $.plant^{-1}$ | | | Spikelet number $.ear^{-1}$ | | | Total dry weight $.plant^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | LP | | KT | LP | | KT | LP | | KT |
| HH | 3.30a | * | 2.90a | 18.60a | * | 15.40a | 0.64a | * | 0 20a |
| LL | 1.40b | * | 1 00b | 12.20b | | 13.00b | 0.19b | | 0.14b |
| Mean | 2.35 | * | 1.95 | 15.40 | * | 14.20 | 0.41 | * | 0.17 |
| VC% | | 26 17 | | | 9.60 | | | 38.00 | |

(HH) high and low (LL) nitrogen during all cycle, (HL) high nitrogen till maximum floret number and afterwards solution L; (LH) low nitrogen till maximum floret number and afterwards solution H.

Figures followed by the same letter do not differ between them. (*) significant differences between cultivars (P: 0.05). VC%: Variability coefficient in percent. Valid for all Tables.

previous results of Single (1964), Beveridge *et al.* (1965) and Langer & Liew (1973). This effect was greater on the semi-dwarf cultivar La Paz INTA, where reductions of 34 and 70% were registered for spikelet number and dry weight.plant$^{-1}$, while for Klein Toledo these values represented reductions of only 16 and 30%, respectively. Tiller number.plant$^{-1}$ and total dry weight.plant$^{-1}$ were well correlated in both cultivars, r: 0.87** (p: 0.01) and r: 0.60** (p: 0.01) for La Paz INTA and Klein Toledo, respectively. As previously demonstrated by Caldiz & Sarandón (1988) with their shading experiments, spikelet number.ear$^{-1}$ was positively correlated with total dry weight.plant$^{-1}$ (r: 0.75**; p: 0.01; for La Paz INTA), confirming that availability of assimilates defines spikelet production. Again the semi-dwarf cultivar was more sensitive to N shortage, as it was to light reduction.

Also at stage (2) N shortage significantly reduced all the variables measured. Caldiz & Sarandón (1988) found that maximum floret number was not reduced by shading and in this work N shortage hardly decreased this parameter. It seems that it is less sensitive to environmental changes than other parameters. As in stage (1), spikelet number.ear$^{-1}$ and total dry weight.plant$^{-1}$ were correlated for both cultivars, r: 0.93** (p: 0.01) and 0.80** (p: 0.01) for La Paz INTA and Klein Toledo, respectively. Again, reductions in total dry weight.plant$^{-1}$ due to N shortage were much more higher in La Paz INTA than in Klein Toledo (Table 2). Probably tall cultivars are better buffered against environmental constraints, as previously suggested by Fischer & Hille Ris Lambers (1978) and Caldiz & Sarandón (1988).

Semi-dwarf wheat cultivars were defined by Dalrymple (1986) as high yielding. This is in close relationship to the potential yield of such cultivars, which is partially defined early in the season. In this work, La Paz INTA achieved a higher number of potential grain sites with respect to Klein Toledo, when grown either, under high (HH and HL) or low (LH and LL) nitrogen (Figure 1). Reductions of 72% in the number of potential grain sites were recorded for both cultivars for HH, of 78% for HL, of 85% and 88% for LH and of 86% and 87% for LL in Klein Toledo and La Paz INTA, respectively (Figure 1). When plants of both cultivars were grown under high N early in the season they achieved a great initial number of potential grain sites. Later N supply did not increase the number of potential grain sites, hence the "sink effect" due to grain number could be reduced.

After the addition of N at stage (2) tiller production in treatments LH was increased; as already mentioned, the sink (grain number.ear$^{-1}$), in the main stem, for that additional N was smaller for LH than in the HH treatments (Table 3). Nevertheless, these late developed tillers were very small and would contribute to a minor extent to grain yield.

Under continuous low N supply (LL) fertile spikelet.ear$^{-1}$ and grain number.spikelet$^{-1}$ were reduced, while grain weight was higher than in the LH treatment. This was probably due to the high tiller-grain competition between the late developed tillers and the main stem that took place in treatment LH, due to its higher number of late developed tillers. These results also confirm Reilly's (1984) results, that "de novo" nutrient assimilation continues in cereals well after anthesis due to a significant retention of root function.

**Table 2.** Tiller number per plant, maximum floret number per spikelet and total dry weight per plant at maximum floret number stage (2) for both cultivars, La Paz INTA and Klein Toledo (KT).

| Treatments | Tiller number .plant$^{-1}$ | | Maximum floret number .spikelet$^{-1}$ | | | Total dry weight .plant$^{-1}$ (g) | | |
|---|---|---|---|---|---|---|---|---|
| | LP | KT | LP | | KT | LP | | KT |
| HH | 3.70a | 2.30a | 7.75a | * | 8.00a | 1.16a | * | 0.77a |
| LL | 1.60b | 1.60b | 7.25b | * | 7.60b | 0.29b | | 0.40b |
| Mean | 2.65 | 1.95 | 7.50 | * | 7.80 | 0.72 | * | 0.58 |
| VC% | 39 | | | 4.96 | | | 32 | |

References and abbreviations as in Table 1.

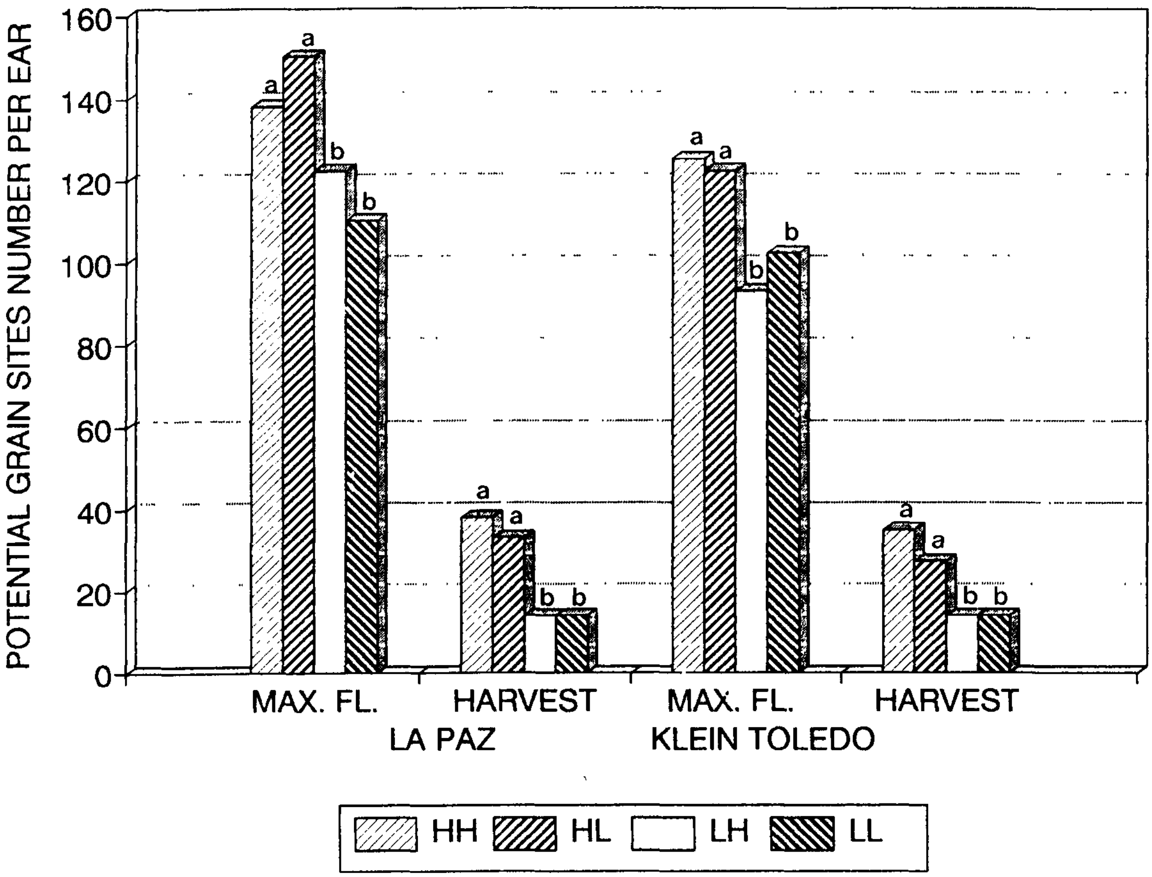


**Figure 1.** Potential grain site number per ear at maximum floret number stage (Max Fl.) and at harvest for both cultivars, La Paz INTA (LP) and Klein Toledo (KT)
References and abbreviations as in all Tables Data were obtained from the averages values of potential grain sites (maximum spikelet number.ear$^{-1}$ x maximum floret number.spikelet$^{-1}$) compared with grain number ear$^{-1}$ in the main stem at harvest. Bars with the same letter do not differ between them ($P < 0.05$).

Other variables measured at harvest, like ear lenght, ear weight, etc. were highly influenced by early N supply and later addition did not modify such situation. No varietal differences were registered in these variables (Table 3). At harvest, no yield differences were found between cultivars, which demonstrate that the effect of N shortage was similar for both cultivars (Table 3).

Furthermore, the reduction in the number of potential grain sites, as showed in Figure 1, and its post-effect upon grain number.ear$^{-1}$ requires more attention, due to its probably impact upon grain.m$^{-2}$. When high yields are the goal and when no other limitations exists, early N supply seems to be the key to achieve such results. From this experiment it can be concluded that grain yield is being defined since the beginning of the crop, due to the early effects upon yield components, which are more evident for the new semi-dwarf cultivars. Hence, the introduction of new high yielding cultivars must be associated with an improvement in crop environment (nutrient, water, etc.) so they can express its true yielding potential.

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**Table 3.** Yield components and grain yield in the main stem, and tiller number.plant$^{-1}$ at harvest, for both cultivars, La Paz INTA (LP) and Klein Toledo (KT).

| Treatments | Fertile tiller number.plant$^{-1}$ | | Grain yield (g) | | Ear weight (g) | | Fertile spikelet number.ear$^{-1}$ | | Grain number .spikelet$^{-1}$ | | Grain number .ear$^{-1}$ | | Grain weight (mg.grain$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LP | KT | LP | KT | LP | KT | LP | KT | LP | KT | LP | KT | LP | KT |
| HH | 2.08b | 3.85a | 1.23a | 1.09a | 1.62a | 1.46a | 14.05a | 12.90a | 2.62a | 2.59a | 37.93a | 34.95a | 32.73a | 31.51a |
| HL | 1.20c | 1.70b | 1.03b | 0.93b | 1.38a | 1.27a | 13.85a | 12.93a | 2.33b | 2.14b | 33.35b | 26.87b | 31.30a | 34.82a |
| LH | 3.10a | 3.50a | 0.37b | 0.42c | 0.48b | 0.58b | 7.72b | 7.75b | 1.78c | 1.85c | 13.75c | 14.37c | 29.75b | 29.75b |
| LL | 1.24c | 1.20b | 0.48b | 0.44c | 0.64b | 0.57b | 7.70b | 8.10b | 1.78c | 1.70c | 13.80c | 13.80c | 34.68a | 32.08a |
| Mean | 1.90 | • 2.56 | 0.78 | 0.72 | 1.03 | 0.97 | 10.82 | 10.17 | 2.13 | 2.07 | 24.68 | 22.50 | 31.76 | 32.08 |
| VC% | 14.20 | | 20.55 | | 18 | | 12.15 | | 8.27 | | 21.7 | | 4.80 | |

References and abbreviations as in Table 1.

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